DPX Series Service Training

Theory and System Overview

LUNAR

Rev F - 2/2006

DPX consists of 4 Primary Modules

- X-Ray Generation
  - Tube
  - Power Supplies
- X-Ray Detection
  - Detector
  - Counting (AGS)
- Communication
  - Communications with Host PC
  - Error Detection
- Mechanics
  - Motion Control

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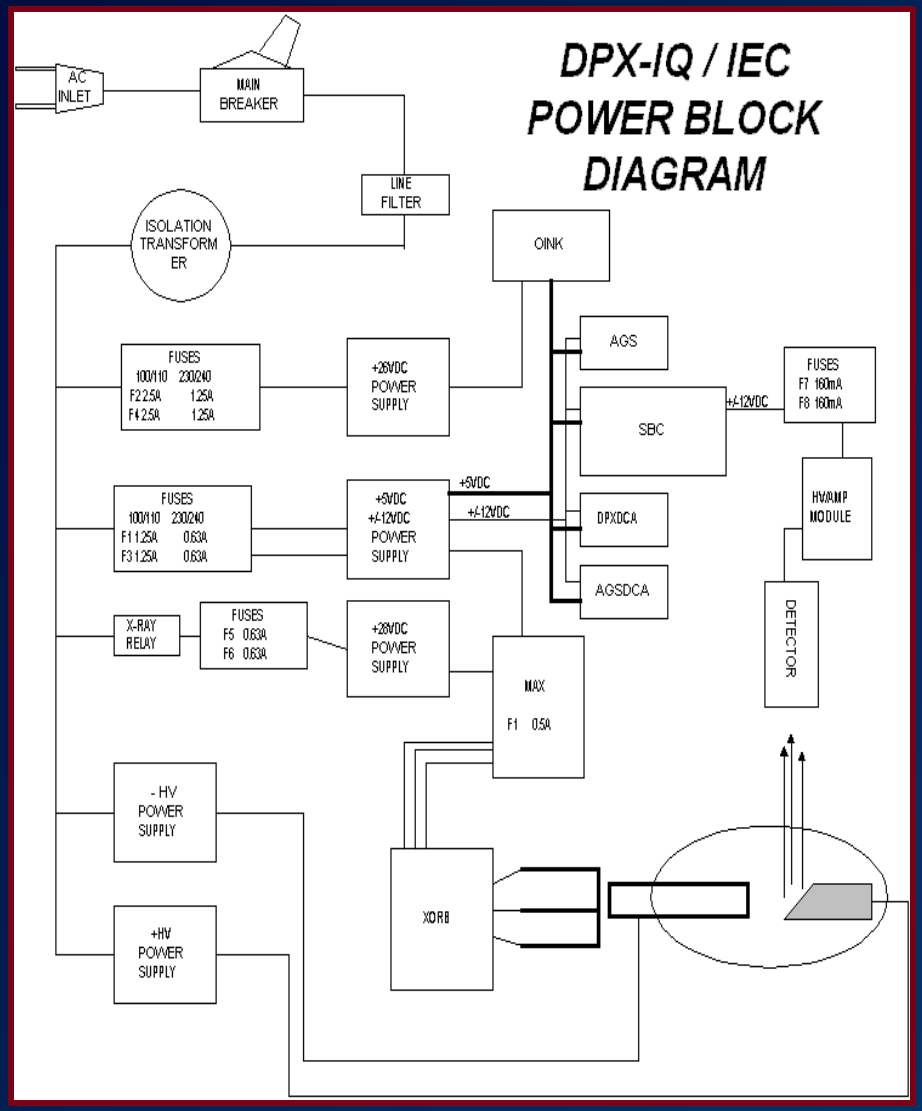
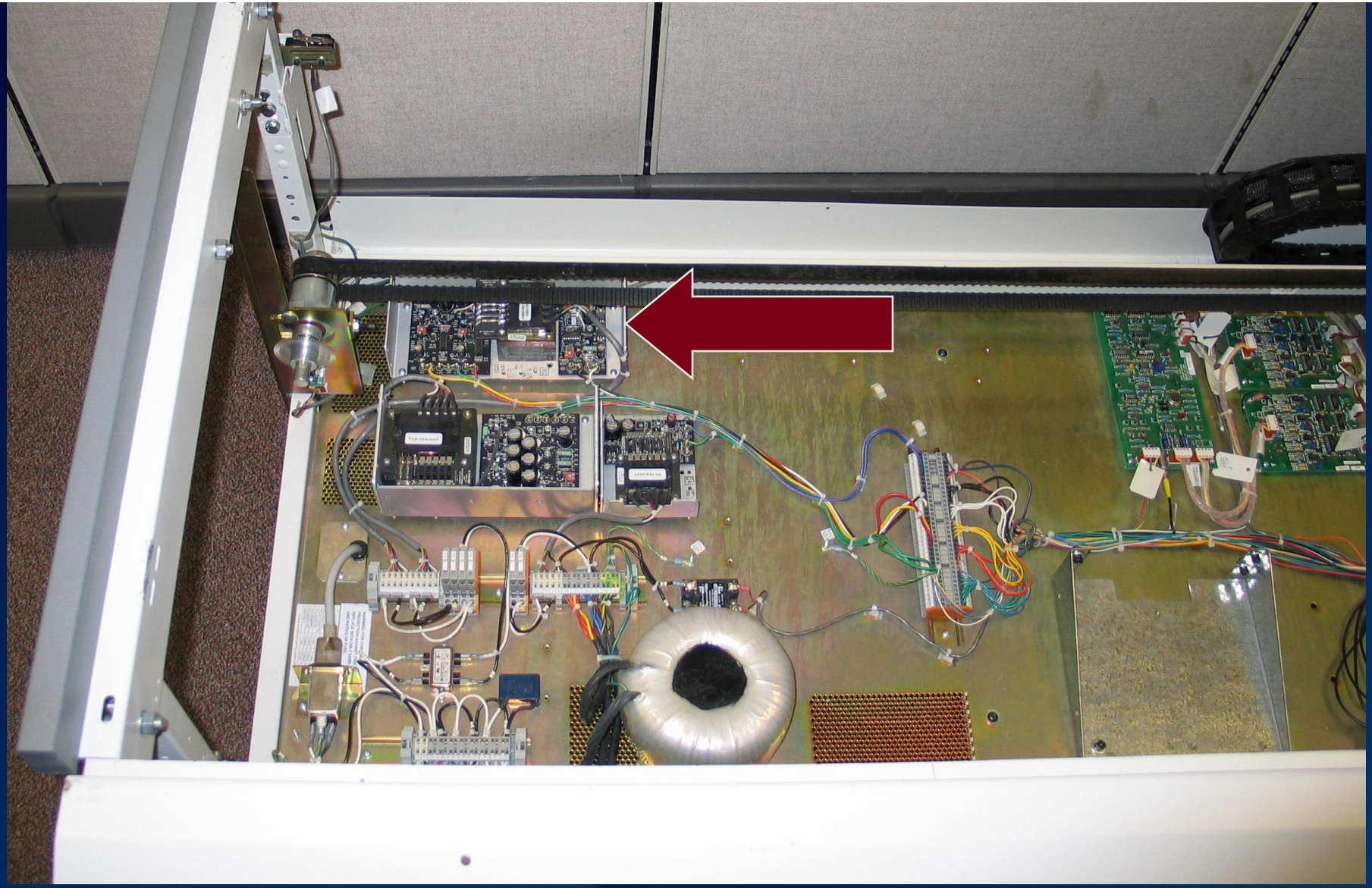
Power Sub-System

Power flow in the DPX-IQ

- AC Isolation Transformer
  - Protects Unit from Voltage transients
- All power supplies are fused individually
- 120 /220 V AC systems alike - only difference is in fusing
- Scanner and PC controller draws 12.5 A max (120V) requires a 15A dedicated line
- 6 Separate Power Supplies
  - +26 VDC (Mechanics)
  - +5 & +/- 12 VDC (Logic and Communications)
  - +28 VDC (Tube Current)
  - 2 High Voltage (X-Ray Generator)
  - 1 High Voltage (X-Ray Detector)

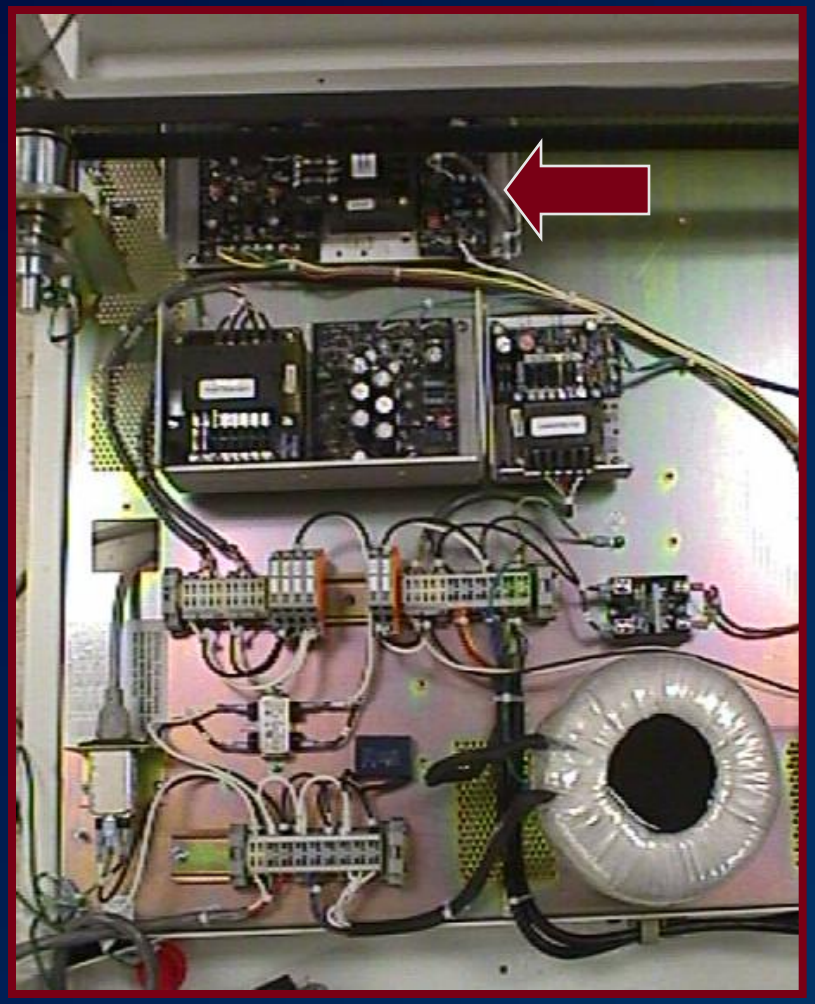


+5 and +/-12 VDC Supply: Scanner Control and Communications



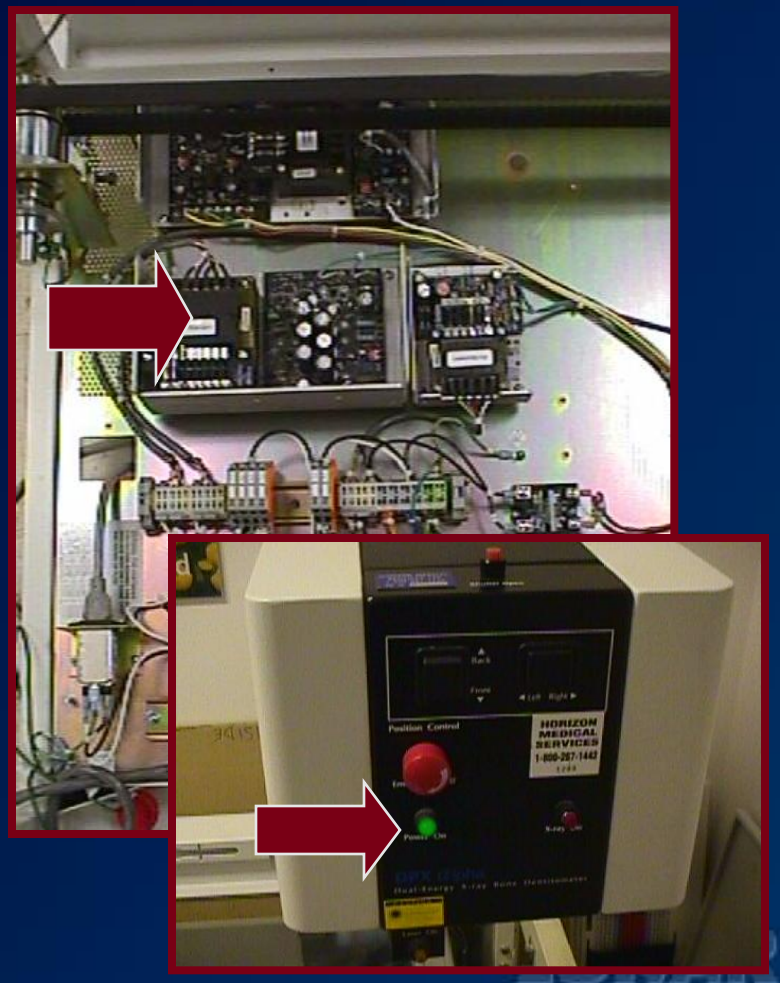
+5 and +/-12 VDC Supply: Scanner Control and Communications

- This power supply drives
  - Logic circuitry (+5)
  - Communications (+/ -12)
    - Between the SBC and the Host Computer
    - CENTENT Pulses
  - Power the detector high voltage power supply (+12)
- Indicator - Amber LED on the SBC

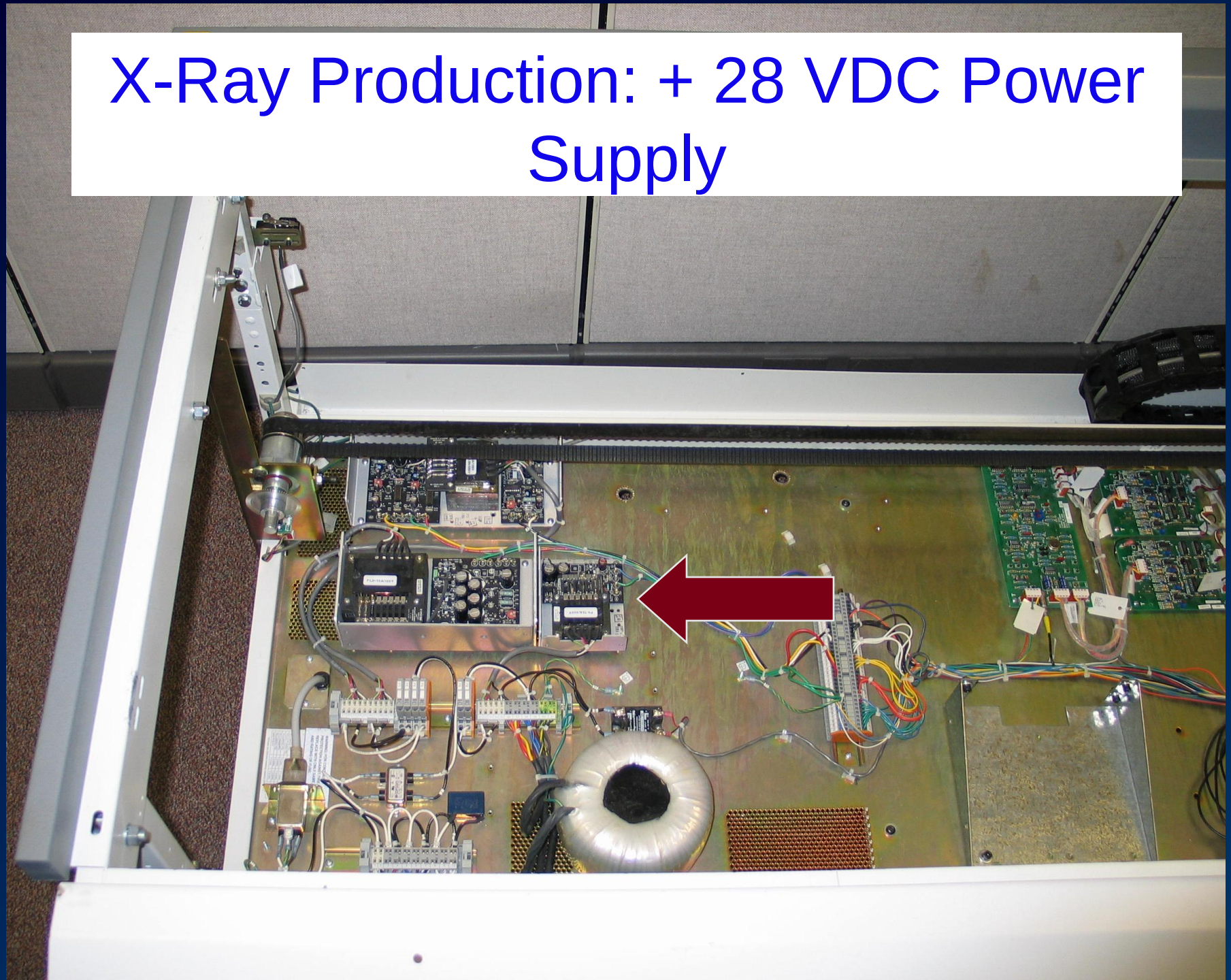


+26 VDC: Drives Motion, Mechanics and Positioning Aid

- Powers Tube Head Fans
- Powers Mechanics
  - Transverse Motor
  - Longitudinal Motor
  - Shutter / Collimator Solenoids
- Powers Patient Positioning Aid
  - (Laser or large LED)
- Green light on scan arm is lit when this power supply is on.

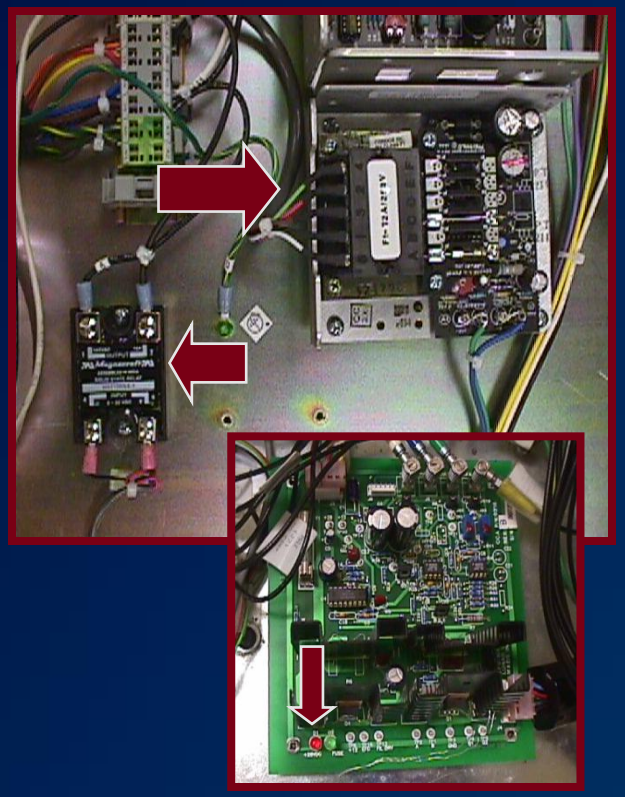


X-Ray Production: + 28 VDC Power Supply



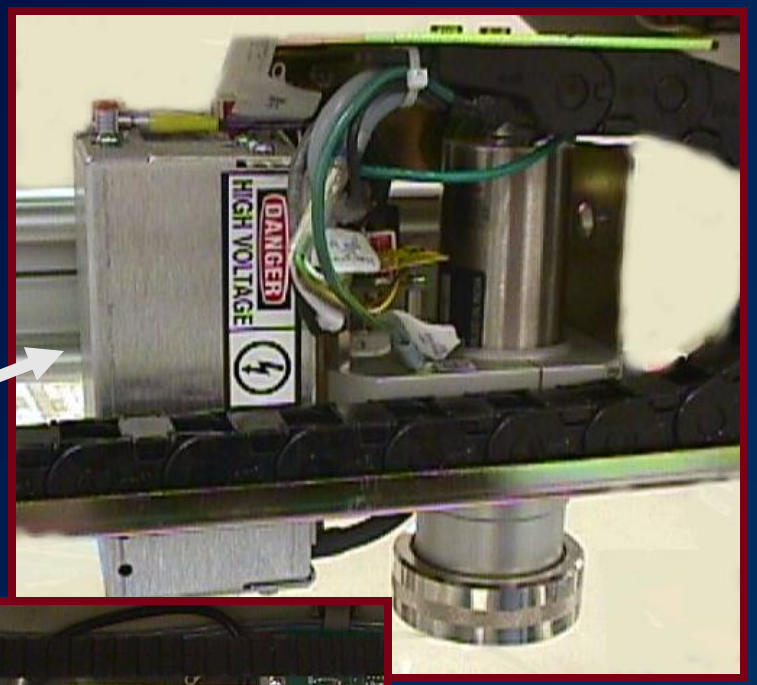
X-Ray Production: + 28 VDC Power Supply

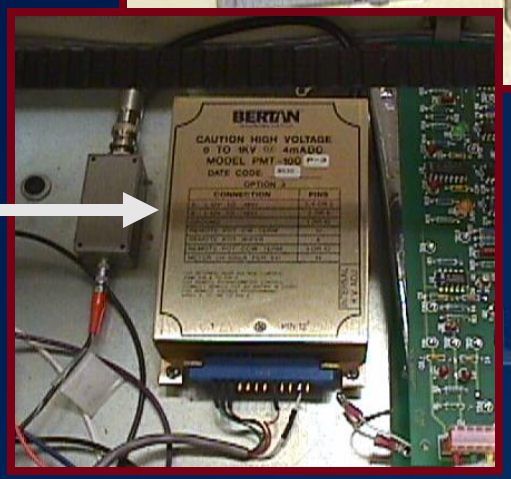
- Dedicated to the X-Ray Tube Head Filament
- Solid State Relay enables Power Supply and Tube Head Filament Transformer
- Only on when X-Ray Tube Head is being ramped up
  - Red LED on MAX Board indicates the presence of +28 VDC



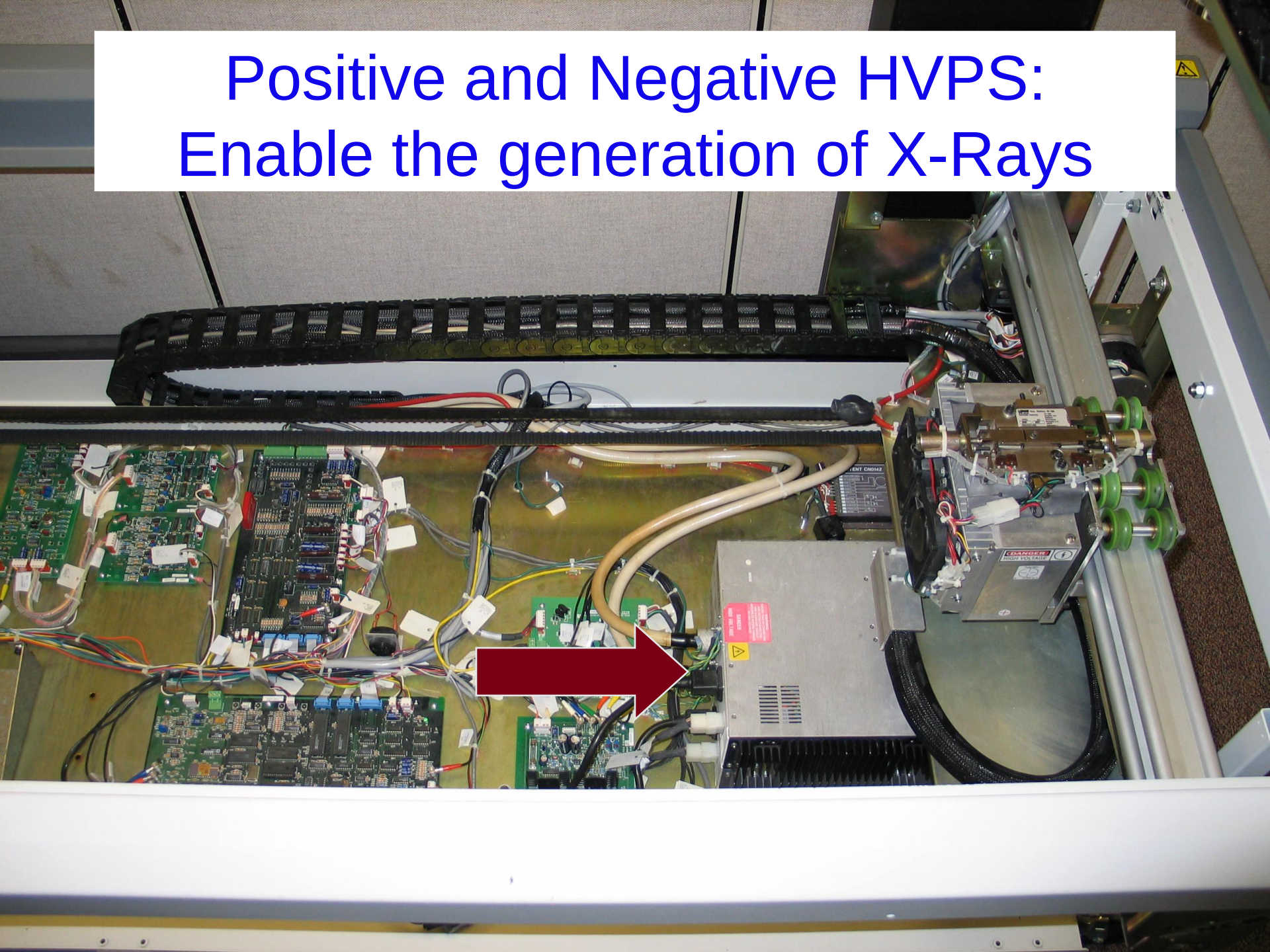
Dedicated HV Power Supply for Detector

- Dedicated to power the detector
- Voltage Potential to 1000 VDC
- Typically 650 - 680 VDC
- Keeping system power on keeps detector at thermal equilibrium
  - Increased detector life
- + 12 VDC input
- IEC Systems
  - AMP Module
    - Incorporates AMP Board and Power Supply into single Unit
- Non IEC Systems
  - Power Supply is in Electronics Pan



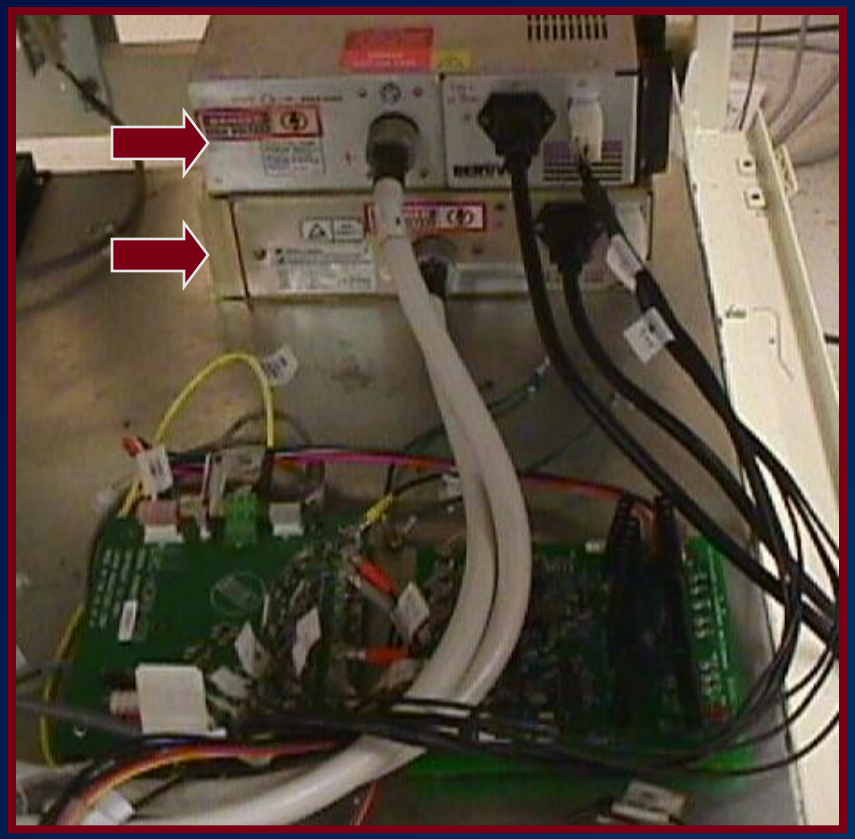


Positive and Negative HVPS: Enable the generation of X-Rays



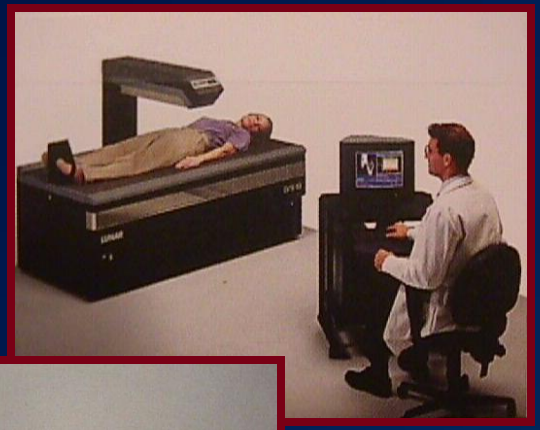
Positive and Negative HVPS: Enable the generation of X-Rays

- Dedicated
- Create 76KeV (38KeV each) potential across X-Ray Tube Head insert
- As soon as 41 KeV potential exists - X-Rays exist
  - Types vary depending on the sub-type of scanner
- Programmed by the SBC
- 3mA Maximum Current



HVPS in High Current scanners: DPX-L, DPX-alpha, DPX-SF and DPX-IQ HVPS

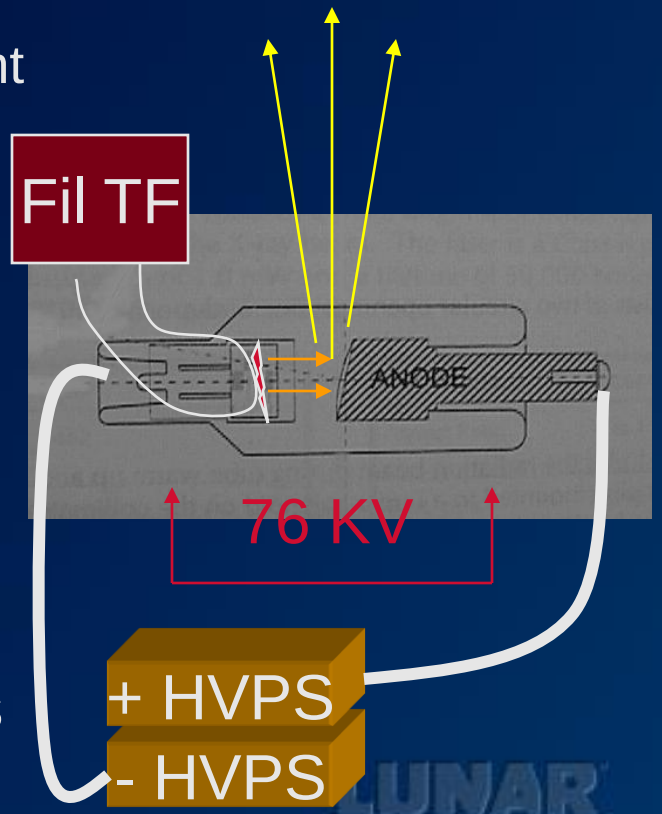
- New Spellman or Bertan
  - Units from the two vendors are interchangeable
  - Can mix and match but not recommended
- 3.0 mA Maximum Current
- Input from AC line
- Protected by Isolation Transformer
- +/- 40 KeV DC (38 KeV per power supply)
- Service Tip: Use care when changing power supplies - mounting screws are different lengths always use the short



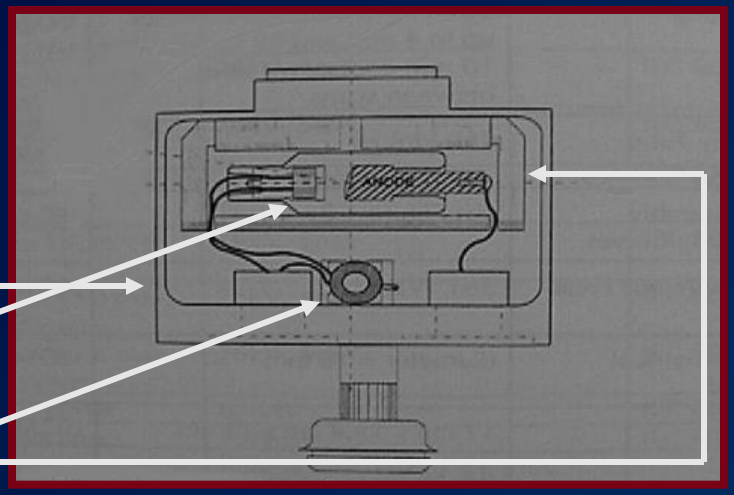
X-Ray Production Subsystem

Basic Theory of X-Ray Production

- Tube Head Insert
  - fixed anode
  - Filament
    - Warm it up - low current from Filament Transformer
  - 76 KeV Potential across Insert (0.150mA to 4.750mA)
  - Electrons (-e) “boil off of filament” (Cathode)
- -e Accelerated across 76 KeV potential strike Tungsten Target (Anode) knocks an -e off of target, as another e- falls into the orbit an X-Ray (Photon) is produced



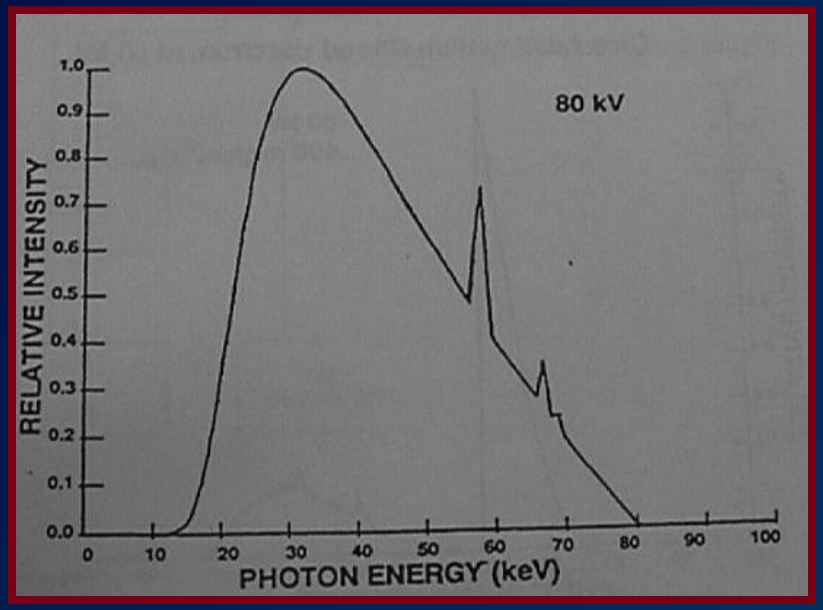
Components of the LUNAR DPX X-Ray Tube Head



- FDA certified component
- Lunar Manufactures
- Oil Filled Metal Housing
- Fixed Anode X-Ray Insert
- Lead Shielded
- Filament Transformer
- Beam Hardening - Tungsten is boiled off of Anode (pits) and collects on the glass of the insert - absorbs X-Rays
  - Pitting due to high temperature - damages Anode focal Spot
- Filament can burn out (similar to incandescent light bulb)
- Oil leak possible causing arcing due to air in tube

X-Ray Production in the LUNAR DPX Tube Head

- X-Ray Tube Ramped up to proper operating voltage and current (HVPS)
- X-Ray Insert Converts current into X-Rays
- Produces broad spectrum of photon energies (15-80KeV)



Unfiltered X-Ray Spectrum at 80 KV

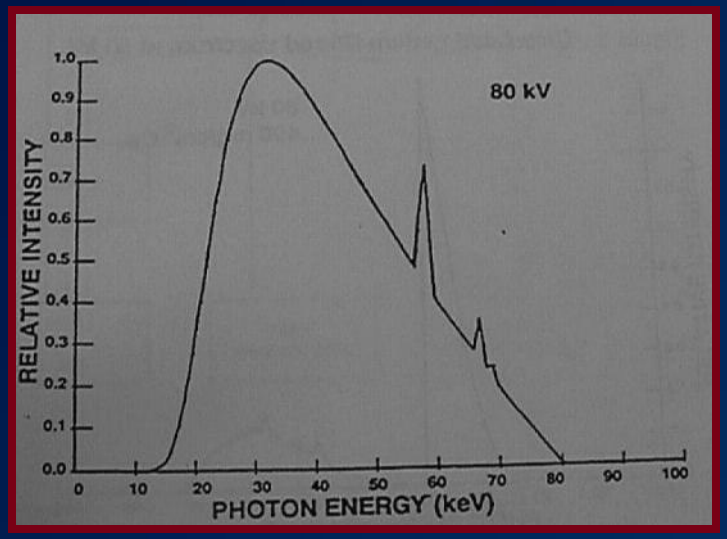
The small peaks are characteristic of the tungsten target used in the tube head insert

Requirements for Accurate Determination of Bone Density

- Two Unknowns in Image
  - Tissue
  - Bone

  Requires two measurements be made of the same area and compared

  Unfiltered Spectrum has single Peak - can only measure attenuation of single uniform substance or an object containing two substances where one of the two has a known value



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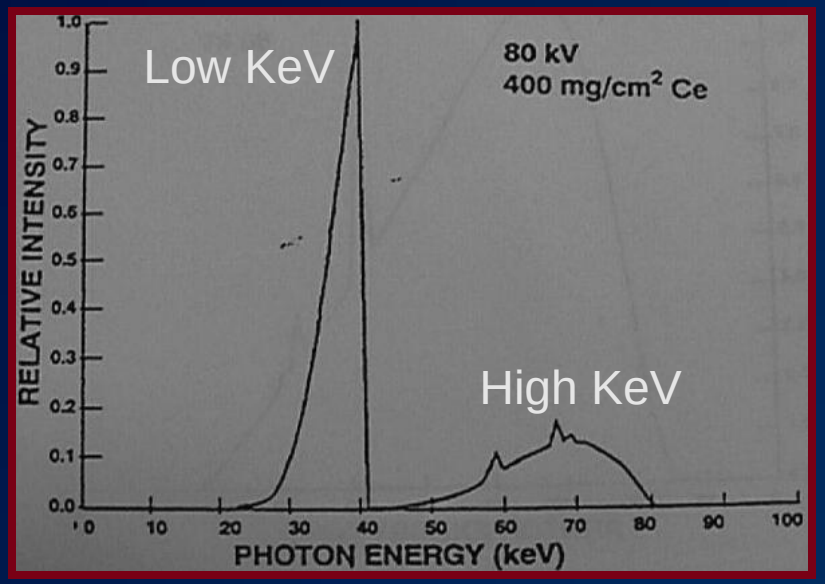
K-Edge Filtration

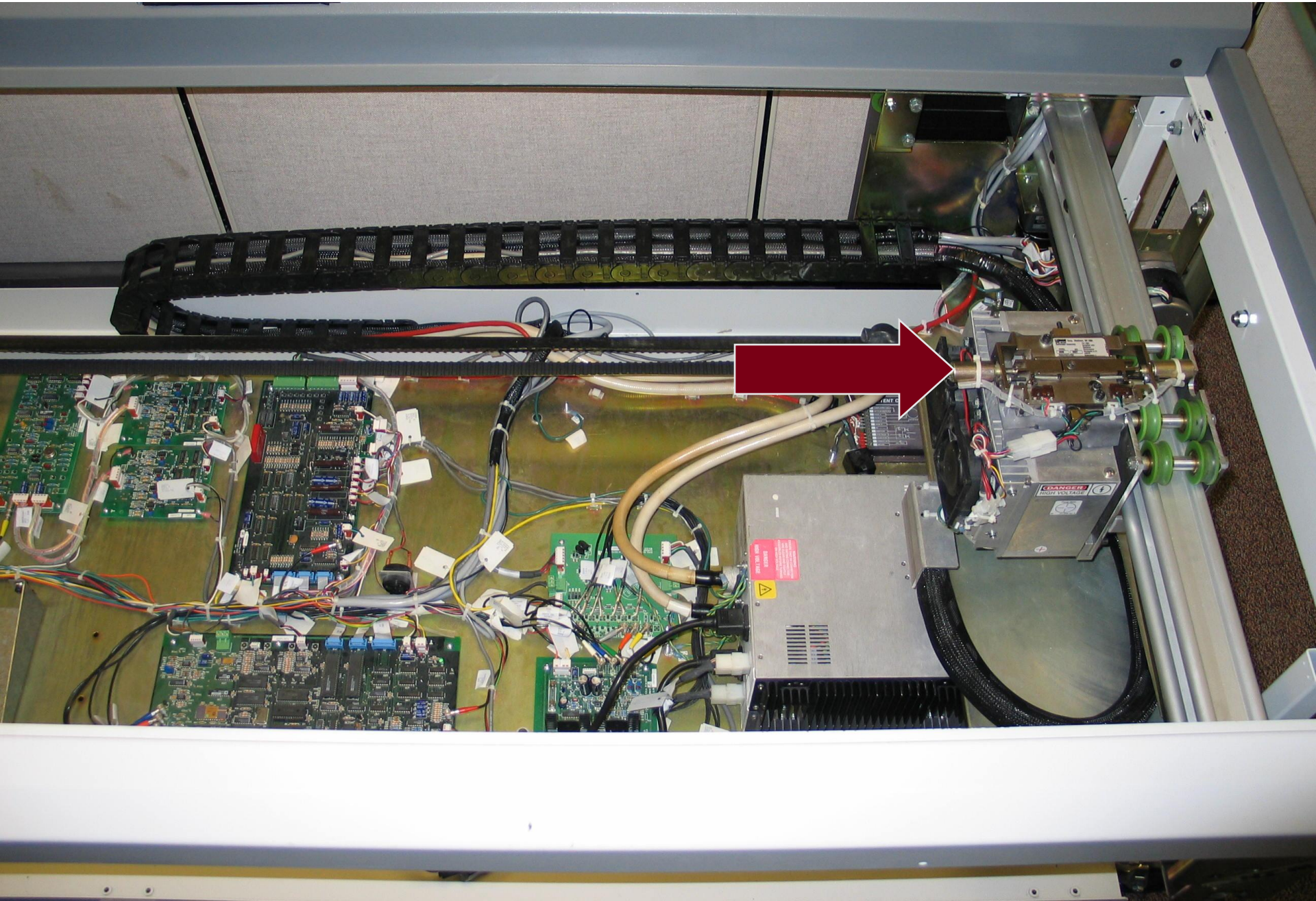
- K-edge filter: Cerium (Ce)
- Ce has a K-shell Absorption Edge at 40 KeV
- Filters both low and high energy photons
- Thickness of filter effects count rate
- Two peaks are visible after the X-Ray beam has passed through the Cerium filter
  - 38 KeV
  - 70 KeV
- Note the relative numbers of counts for the two energy peaks



Collimator

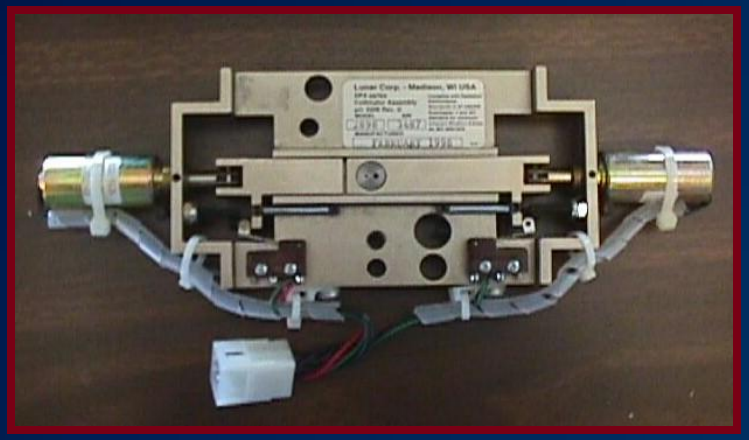
Beam Limiting Device

Collimator: Control of the X-Ray Exposure



Collimator: Control of the X-Ray Exposure

- FDA Certified component
- 2 Slides / 2 limit switches controlled by linear solenoids and springs
  - Shutter
    - blocks beam
    - Tantalum attenuates X-Rays keeps them contained prevents exposure during ramping and patient positioning
  - Collimator slide
    - Determines Beam size
    - two holes
    - 1.68mm (Medium)
    - .84mm (Fine)
    - software determines beam size to limit patient exposure during exam



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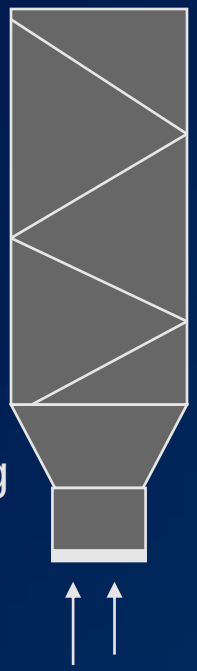
X-Ray Detection Sub System

X-Ray Detection Detector = PMT

- Scintillating Material
  - Sodium Iodide converts photons into visible light, then to an electrical pulse
- Each photon creates a single pulse
  - Pulse Amplitude is directly proportional to the energy of the X-Ray which produced it
  - ~ 6-7 mV for Low Energy
  - ~ 10 mv for High Energy
- PMT - Photo Multiplier Tube increases signal strength
  - Variable HVPS - 1000VDC Max
  - Potential set by SBC typically 600-800 VDC
- Signal out rides piggy back on ~ 700VDC power in
- As scintillation crystal or photocathode deteriorate the detector will loose resolution and must be replaced
  - All counts decrease, lows faster than highs causing air ratio to increase
  - Spillover will also increase due to high energy counts getting weaker



X-Ray Detection

AMP Board

AGS Board

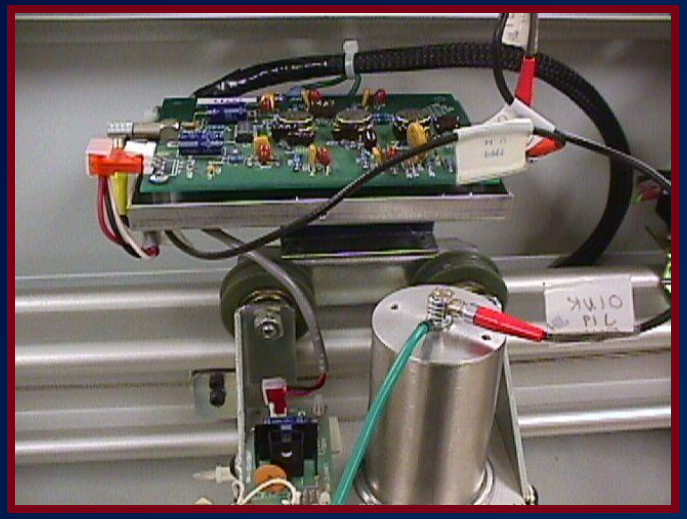
AGSDCA Board

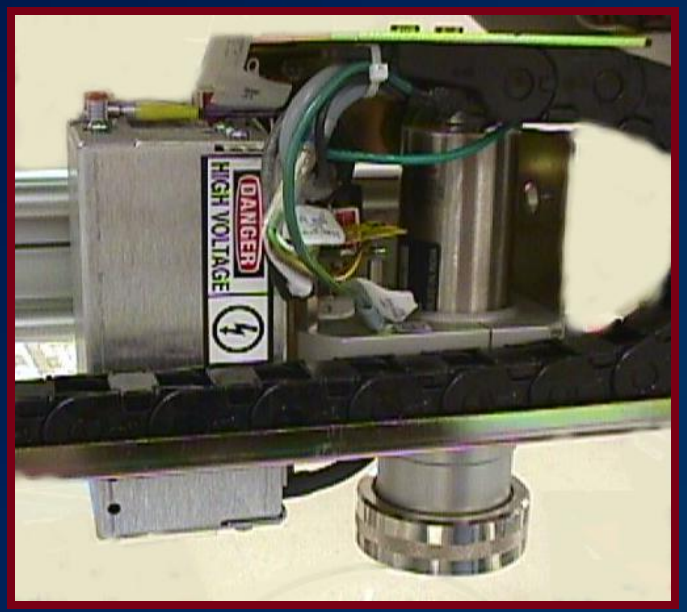
DPXDCA Board

AMP Board

AMP Board - Amplification and Pulse Shaping

- Amplification of charge pulses from the PMT
  - Gain of approximately 240Av
- Shape signal into a stable bipolar pulse
- Drive the pulse down a 50 Ohm coaxial cable to the AGS board (5m of cable)
- + 12 VDC drives amps
- Located next to detector in metal case on IEC Certified systems / part of AMP Module which also includes the detector power supply
- Separate board on older systems (non-IEC)





Troubleshooting the AMP Board

- Symptoms
  - No Counts
  - No Amp / Attenuate Lights on AGS Board
- AMP TP6 to TP4 on AGS should be continuous - if not signal cable break exists
- Never Unplug J2 LEMO (HV in) with scanner power on - it will destroy the AMP Board (ONLY non-IEC systems)

Test Point	Signal	Expected Value
TP 2	Input Pulse	~1.0 mVDC
TP 6	Output (Bipolar Pulse)	~2.4 VDC (High) ~1.6 VDC (Low)
TP 7	+ 12 VDC	~ 12VDC
TP 8	- 12 VDC	~ -12 VDC
TP 9	Ground	~ 0 VDC

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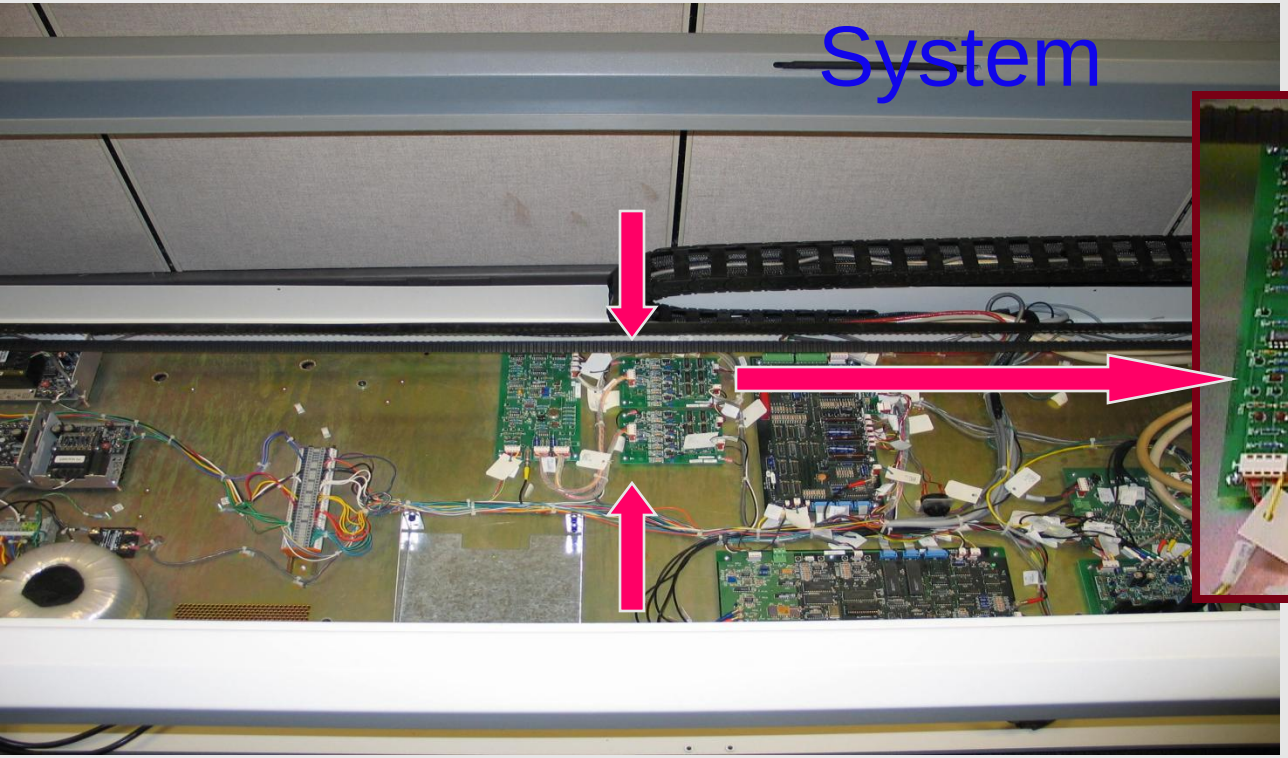
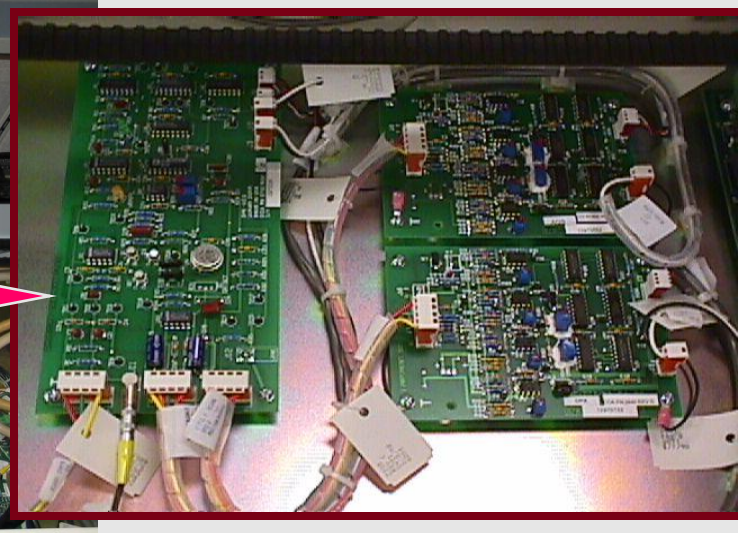
The AGS System

AGS Board

AGSDCA

Overview and Function of the AGS System

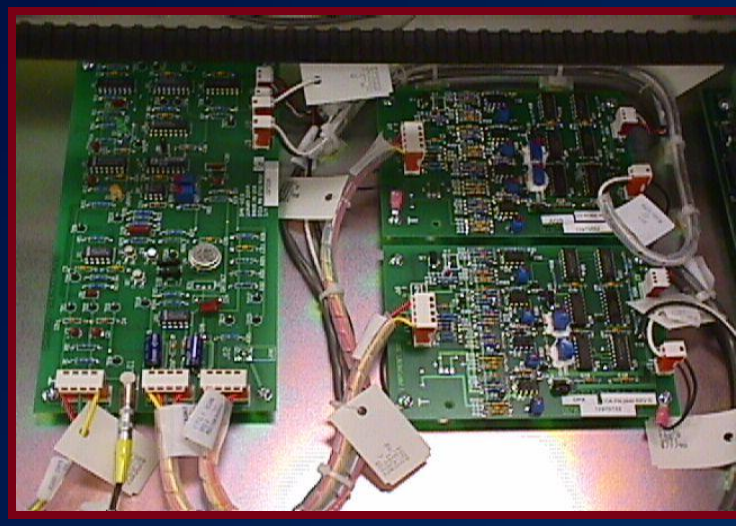




- **AGS (Automatic Gain Stabilization System)**
- **Consists of:**
  - **AGS Board**
  - **AGS DCA (Dual Channel Analyzer) Board**
- **Pulses come in from AMP Board at J11 (TP4)**
- **2.4 VDC bipolar pulse carrying both high and low energy signals**
- **AGS routes same signal to both AGS DCA and DPXDCA (J4 and J7)**
- **Two LED's on AGS Board**
  - **1.Amplify**
  - **2. Attenuate**
- **AGS adjusts gain on High and Low energy signals from input from AGSDCA**
- **OP / CAL Signal - SBC - disables the AGSDCA during the system QA so that the PMT can be peaked**

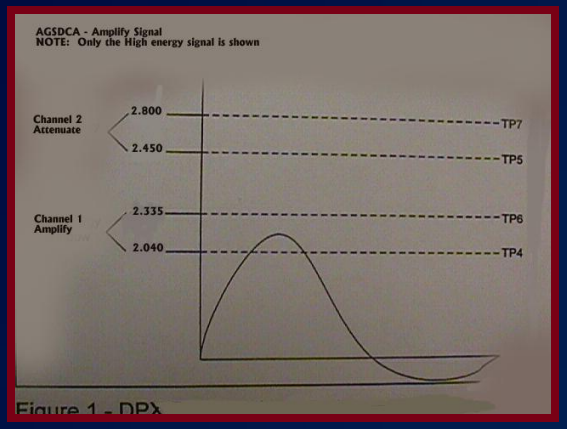
Overview and Function of the AGS System

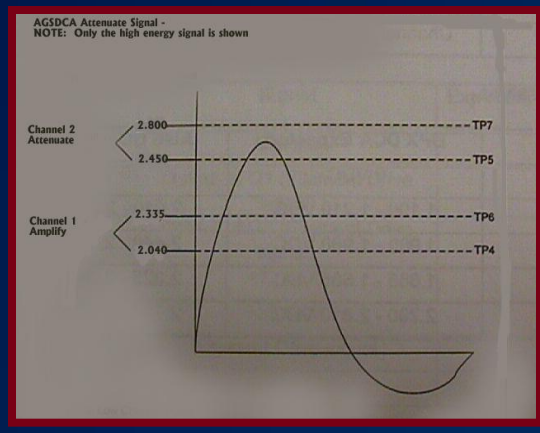
- AGS (Automatic Gain Stabilization System)
- Consists of:
  - AGS Board
  - AGS DCA (Dual Channel Analyzer) Board
- Pulses come in from AMP Board at J11 (TP4)
- 2.4 VDC bipolar pulse carrying both high and low energy signals
- AGS routes same signal to both AGS DCA and DPXDCA (J4 and J7)
- Two LED's on AGS Board
  - 1.Amplify
  - 2. Attenuate
- AGS adjusts gain on High and Low energy signals from input from AGSDCA
- OP / CAL Signal - SBC - disables the AGSDCA during the system QA so



Single Purpose of the AGSDCA Board: Where is the Pulse?

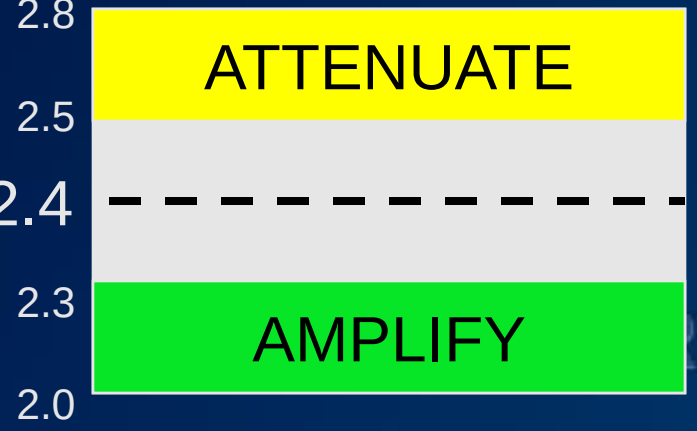
- Compares voltage of High Energy Pulses to set limits
- Sends back logic signal that instructs the AGS Board to Amplify or Attenuate the incoming signal from the PMT
- Gain is constantly adjusted to keep the high energy peak within a preset window
  - (~2.4VDC)
- By stabilizing the gain on the high signal the low is stabilized as well
  - Adjustment is to raw Data
    - Both High and Low Energy Pulses





High energy signal is in Channel 1 window - sends "Amplify" command to the AGS

High energy signal is in Channel 2 window - sends "Attenuate" command to the AGS



DPXDCA

Dual Photon X-Ray Dual Channel Analyzer

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Primary Function of the DPXDCA: Discrimination of High and Low Energy Pulses

- Sends logic signal to SBC for each low and each high energy signal it detects
  - Reads High and Low energy signals
- Does not do the counting only recognition of signal
- Electronically identical to AGSDCA, however, potentiometer settings are very different

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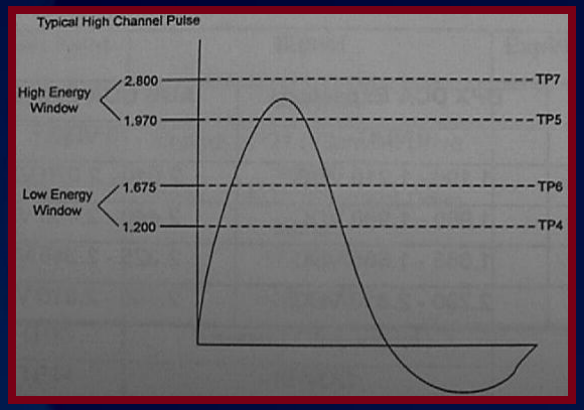
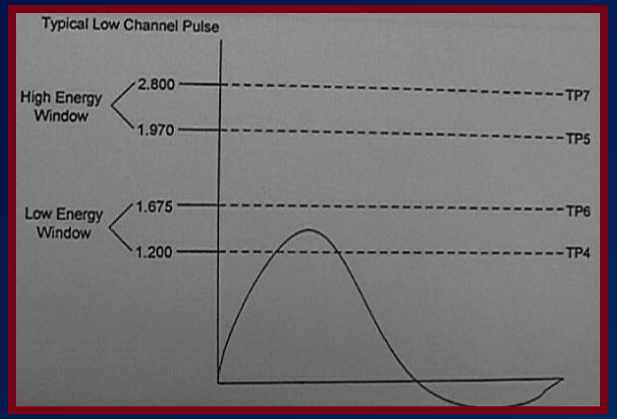
Discriminating High and Low Energy Pulses DPX DCA Windows





A single pulse passes through the high energy window (channel 2) - the DPXDCA sends a single logic pulse to the high energy counter on the SBC

A single pulse passes through the low energy window (channel 1) - the AGSDCA sends a single logic pulse to the low energy counter on the SBC

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SBC Board

Single Board Controller

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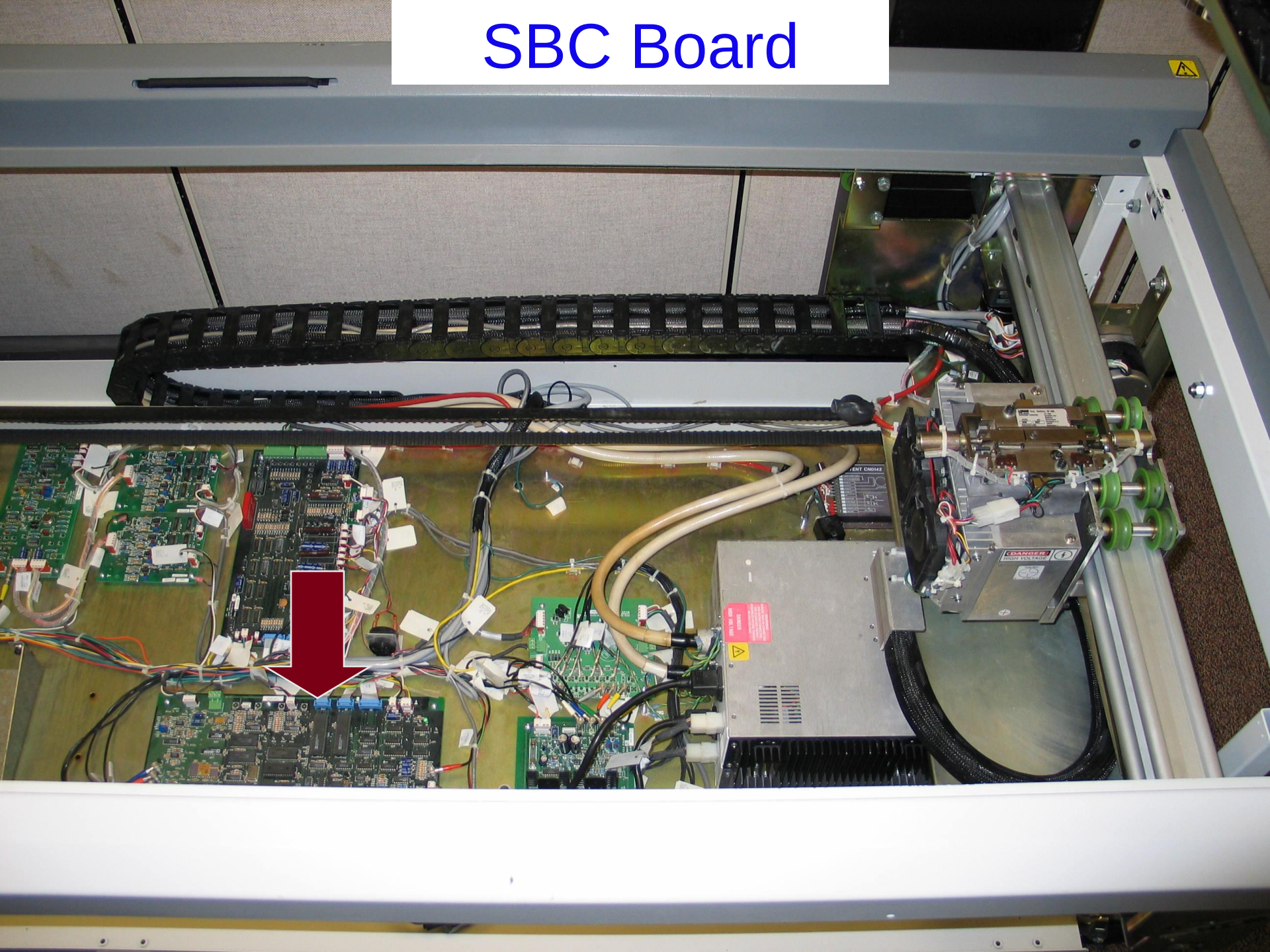
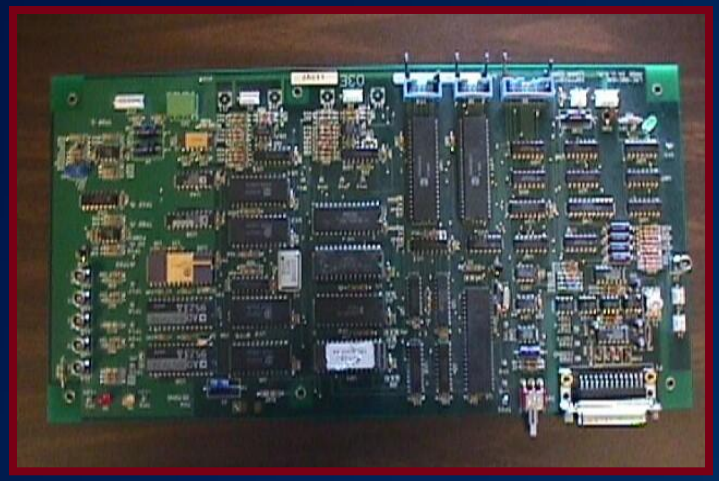
SBC Board



SBC: Scanner Control and Communication Functions

- “Brains” of scanner
  - 8032 Intel Processor
- Overall operation and control
  - Motion control
  - pulse counting
  - limit switch sensing
  - Thermocouple Sensing
  - HV and Current settings



- RS232 communications with host computer
- 56 K available memory

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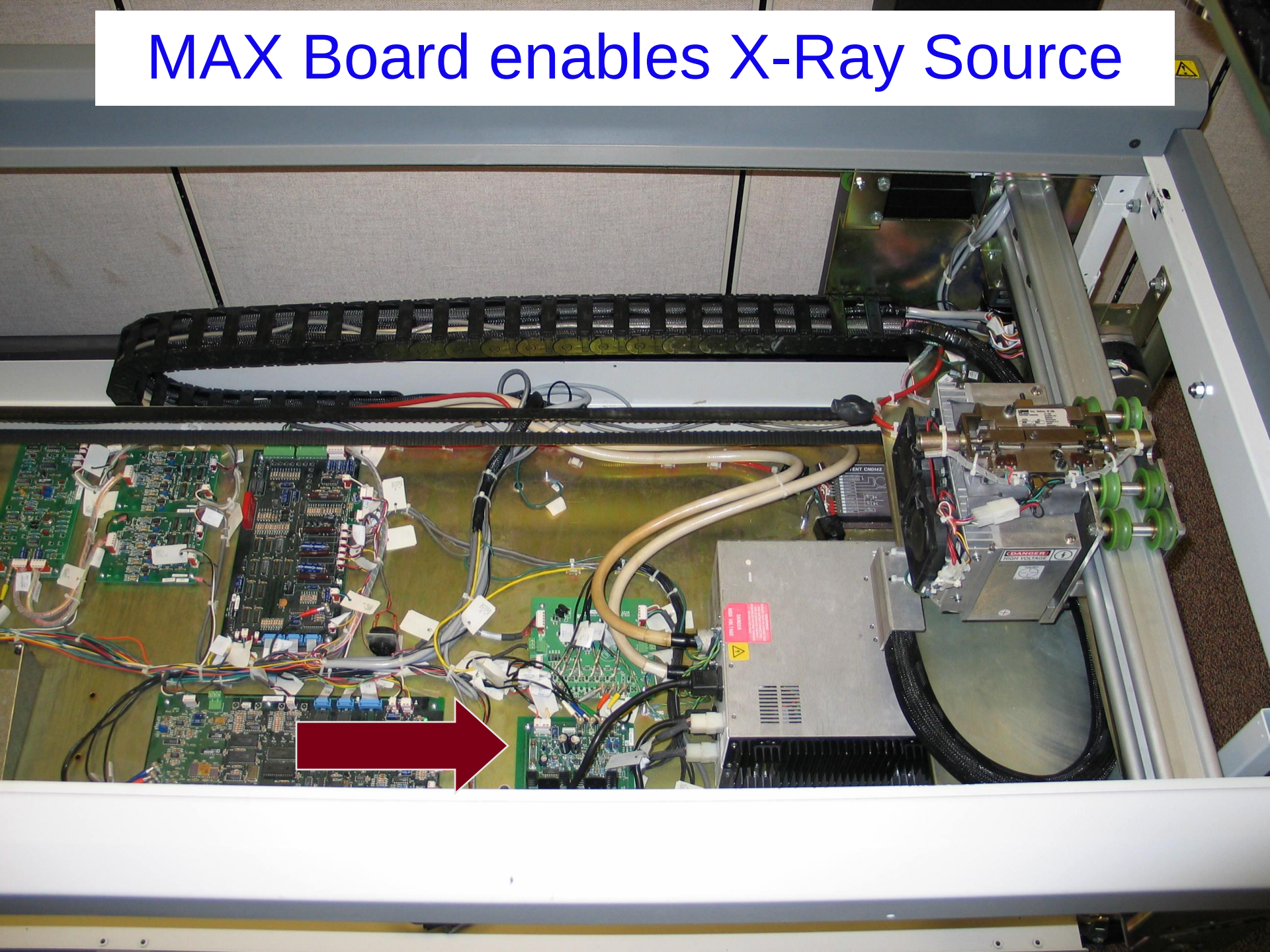
SBC Microprocessor Reset

- The Processor will reset itself
  - if the scanner is powered up
  - if the Comm port is interrupted
  - if other circuit boards fail (fail safe)
  - if the RESET button on SBC is pressed
  - if the E-Stop button is pressed

An Error has Occurred
See Appendix I

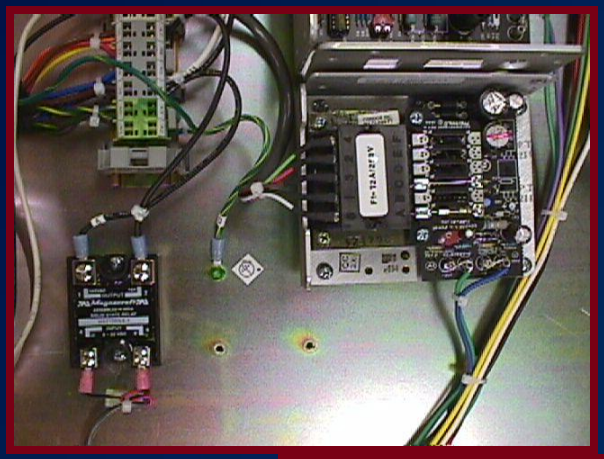
There is no Appendix I

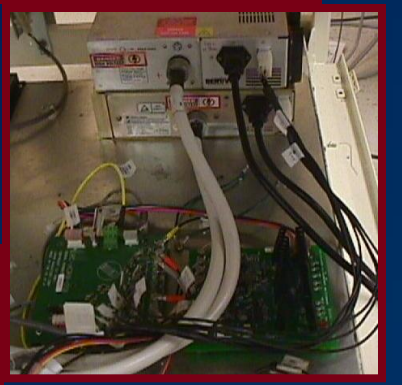
MAX Board enables X-Ray Source

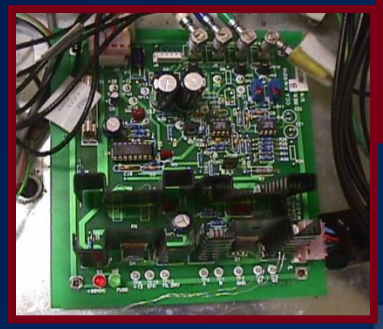


MAX Board enables X-Ray Source

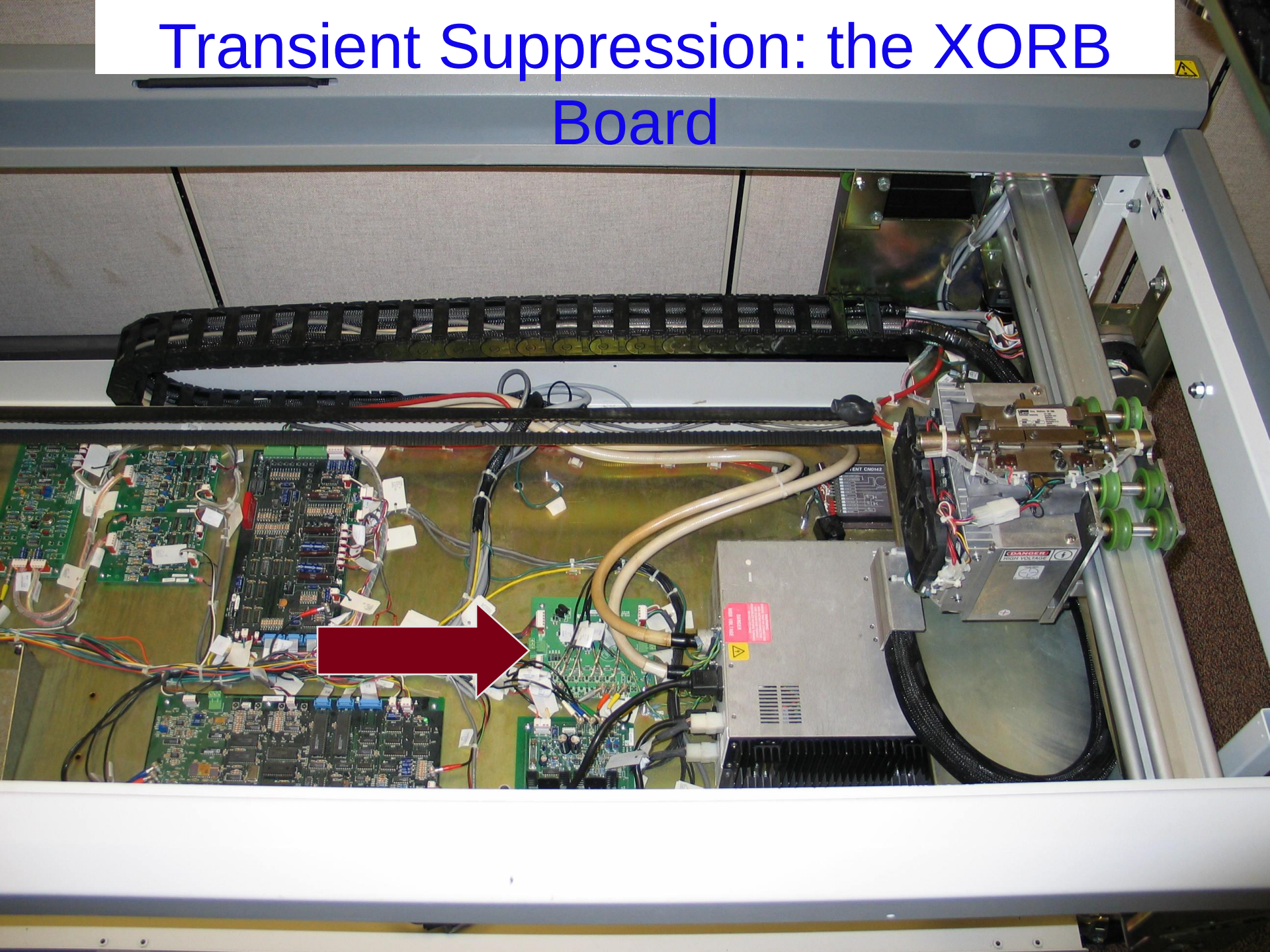
- SBC enables the +28 VDC power supply via the OINK and the High Voltage Power Supplies through the solid state relay
- MAX and Filament Transformer in the Tube Head work with power from the +28 VDC power supply
- MAX regulates X-Ray Insert Filament temperature by controlling the filament current
  - As filament temperature increases the number of electrons available for X-Ray production increases
- SBC reads feedback from HVPS and adjusts filament current accordingly







Transient Suppression: the XORB Board



Transient Suppression: the XORB Board

- Xorb is short for tranzorbs
  - optical isolation of HV and ground
  - protects logic circuitry
- XORB's primary function is to ground out high voltage transients or "spikes" in the X-Ray generation system (logic circuit protection)
- All X-Ray Generation system power flows through the XORB - good place to check signals and power

Test Point	Signal	Expected @ 76kV and .750mA
TP1	-uA Monitor	.750 VDC
TP2	-kV Monitor	3.800 VDC
TP3	-kV Programming	3.800 VDC
TP5	+uA Monitor	.750 VDC
TP6	+kV Monitor	3.800 VDC
TP7	+kV Programming	3.800 VDC

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Mechanics

OINK Board

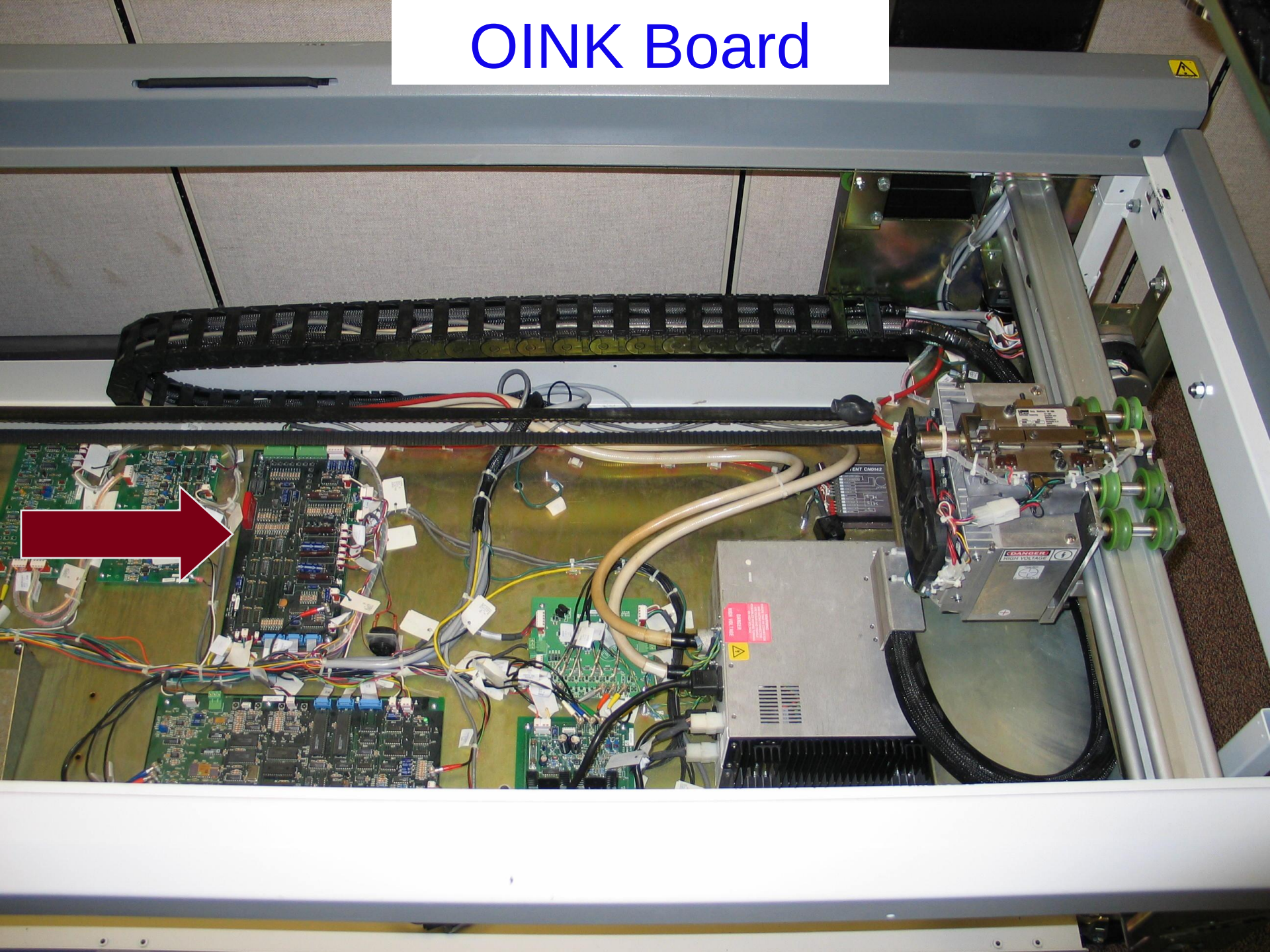
OMI Board

SBC Board

OINK Board

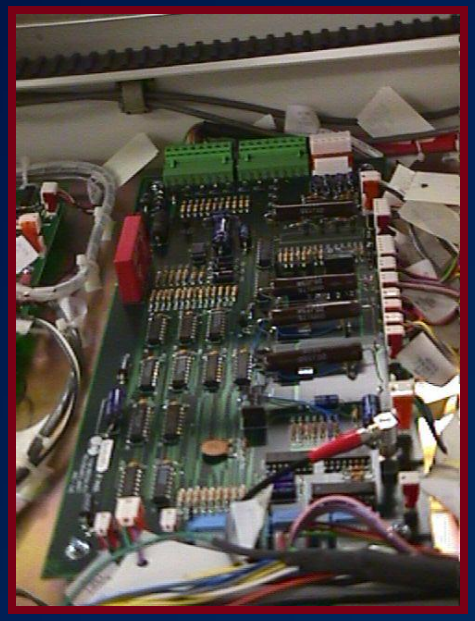
Optical Isolation Noise Reduction (OINR) or (OINK)?

OINK Board



OINK Board Functions

- **4 Main Sections**
  - **Mechanics Control**
    - **Motor Control**
    - **Fan Control**
      - 26 VDC to fans normal operation always on.
  - **User Interfaces**
    - **Indicator Lights**
    - **Rocker Switches for Manual Motion**
  - **Error Detection**
    - **All Subsystems**
    - **E Stop**
  - **Collimator Control**
    - **Solenoids**
    - **Sensing of Collimator Limit Switches**
    - **OINK to collimator also goes through XORB**



Control signals ARE NOT generated here. This is a way-point where control signals generated by the SBC are Optically Isolated

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User Interface: What's the scanner doing?

- Light Indicators
  - shutter light - must illuminate when shutter opens
    - Normally closed circuit
  - x-ray on light - on when >0.1 mA of current runs through tube
    - driven by mA feedback through the SBC
- Patient Localizer (laser)
- Positioning controls on arm
- End of Exposure Alarm
  - triggered by loss of mA feedback or closing of the shutter

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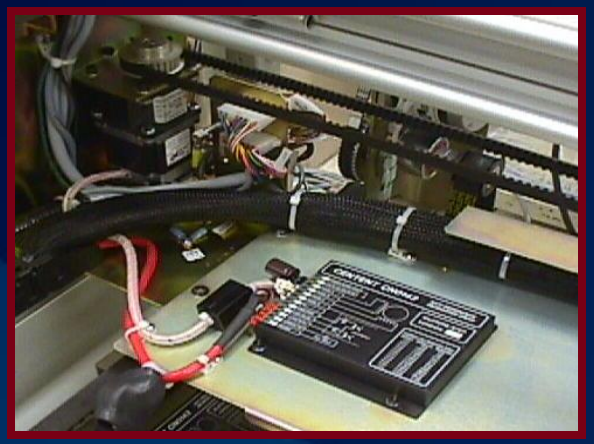
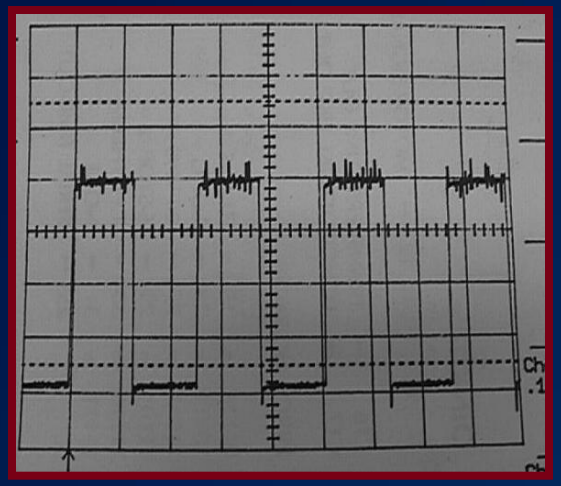
Motor Control: Moving the Scan Arm

- SBC sends commands to OINK - OINK routes to CENTENT
- Commands - Run / Hold and Direction
  - Motors are placed in “Hold” upon generation of X-Rays
  - CENTENT - motor controller
    - Drives Stepper motors
- Different Rev’s of Motors require different wiring configurations - be careful!!

Refer to manual for directions



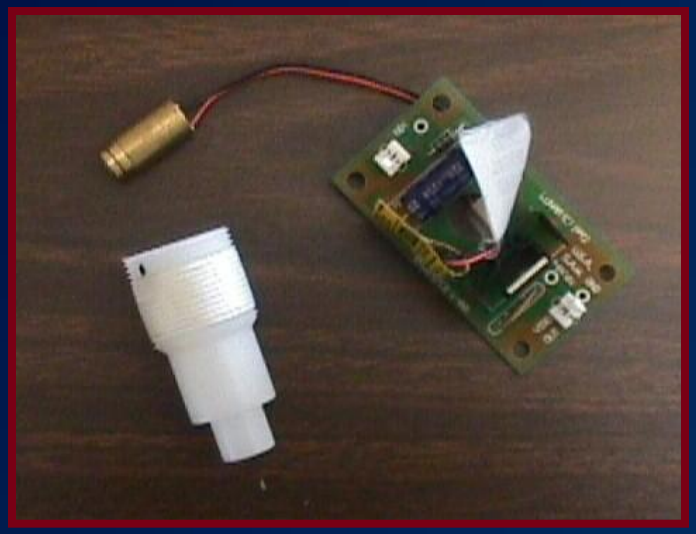


Stepping Pulse

- Sent By SBC
- Measured at OINK TP6 (Transverse) or OINK TP 12 (Longitudinal)

Laser Board: Drives patient Positioning Aid

- This board is idle until the SBC sends a signal to the OINK which in turn sends +26 VDC to the Laser Board.
- The Laser board steps the +26 VDC input down to +5 VDC which activates the Laser
- Do Not Plug / Unplug +26 VDC (Video In) with the power on - this will destroy transistor (Q1) on the OINK and the laser will not turn off



OMI Board

Optical Motion Interrupt

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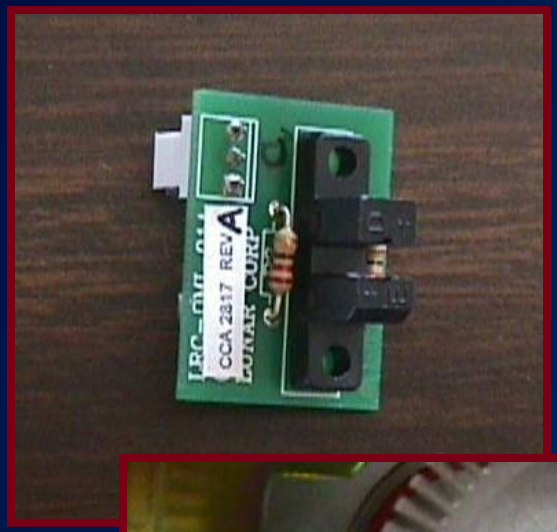
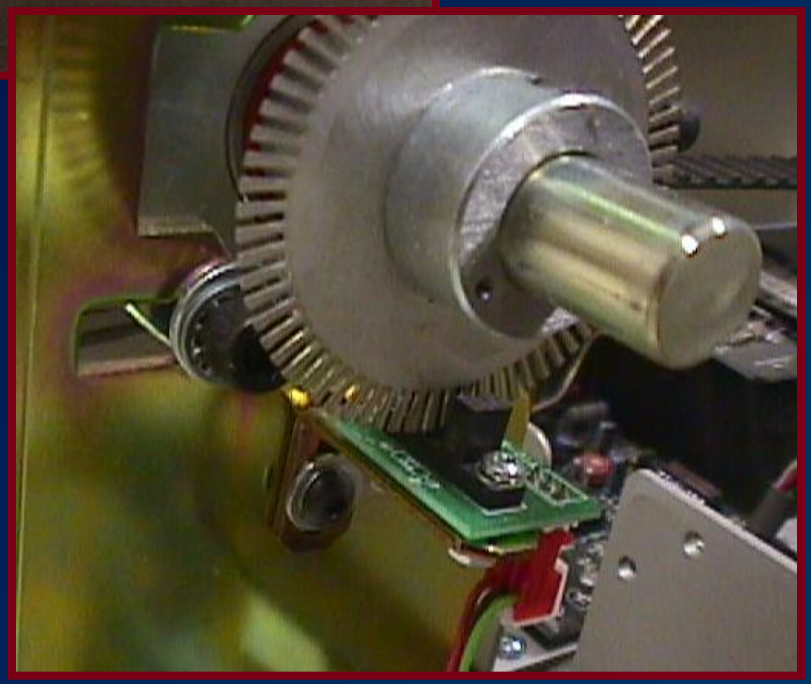
OMI Function: Detect arm movement

- There are 2 OMI's on a DPX series scanner
  - **longitudinal**
  - **transverse**
- These boards have an infra-red beam emitter / detector
- A slotted wheel which rotates while the mechanics are functioning breaks the beam
  - **When the beam is broken the OMI sends a pulse to the OINK**
  - **If the pulses are absent - the OINK reports a motion error**





Sub-system interaction: putting it all together

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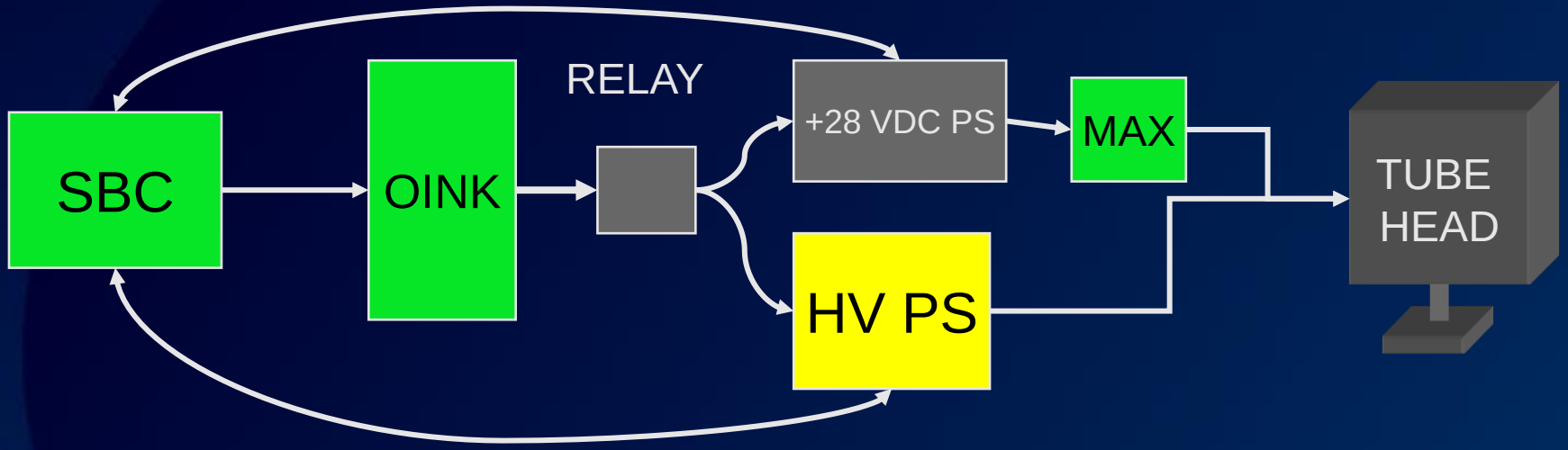
X-Ray Production: + SBC is the command, OINK is the key and the relay is the lock



- The SBC sends the command to generate X-Rays to the OINK
- The OINK trips the relay
- The relay turns on AC to the +28 VDC supply and the HV power Supplies
  - +/- kV flows to the tube head
  - +28 VDC flows to the MAX / Tube head
  - The SBC regulates and monitors the kV and mA following a ramping profile until the desired kV / mA are set

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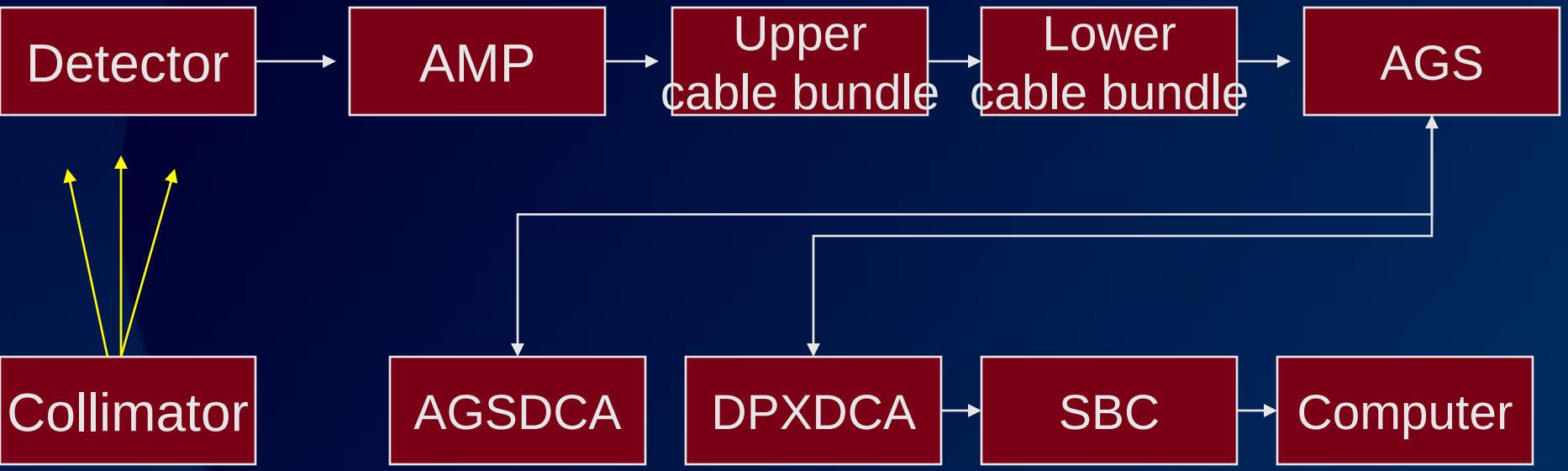
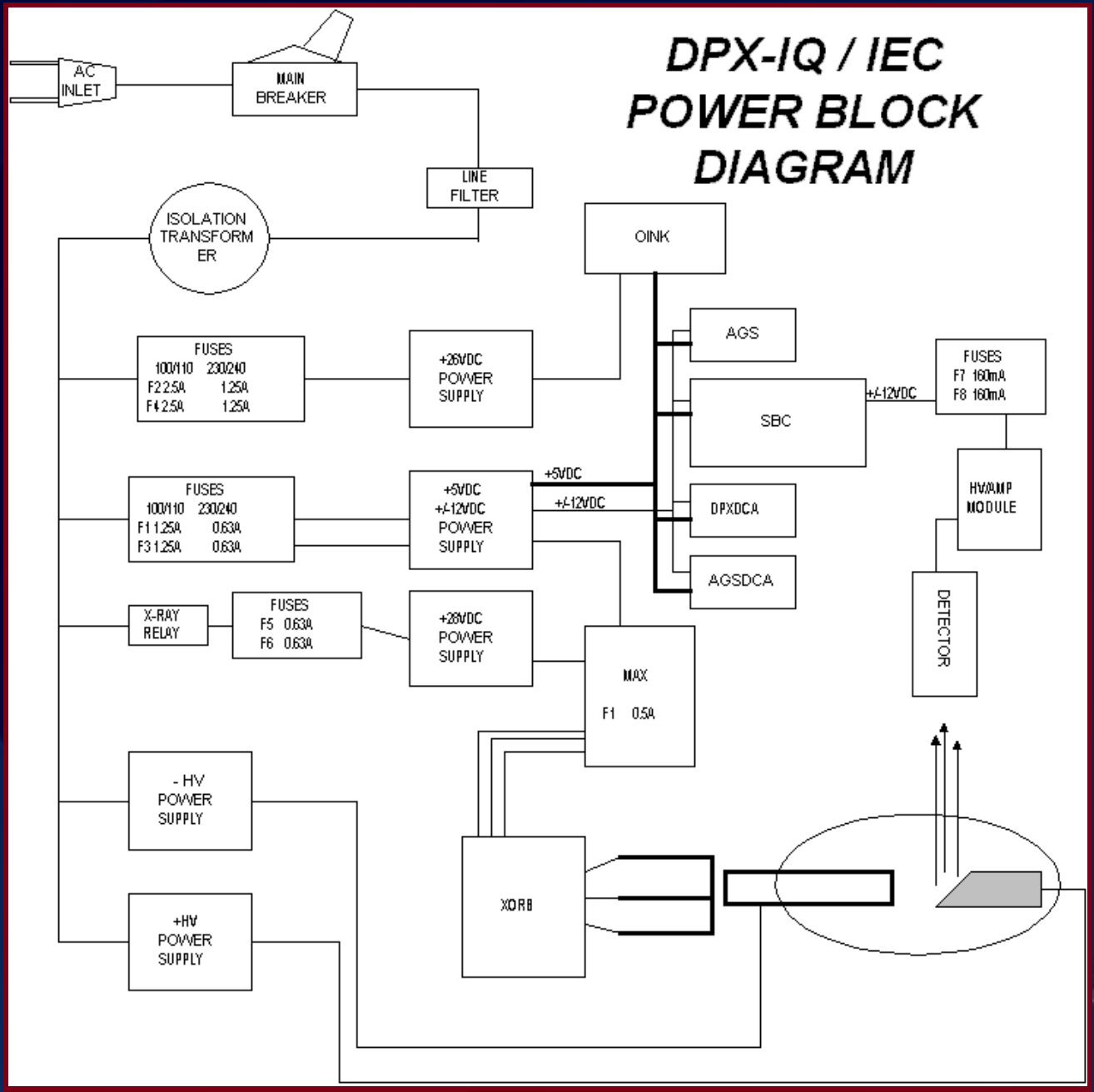
X-Ray Detection: Collimator– Detector– Amp– Upper cable bundle– Lower cable bundle– AGS– AGSDCA– DPXDCA– SBC-- Computer



Review


DPX-IQ / IEC
POWER BLOCK
DIAGRAM
AC INLET
MAIN BREAKER
LINE FILTER
ISOLATION TRANSFORMER
OINK
AGS
SBC
DPXDCA
AGSDCA
FUSES
100/110 230/240
F2 2.5A 1.25A
F4 2.5A 1.25A
+28VDC POWER SUPPLY
FUSES
F7 160mA
F8 160mA
+/-12VDC
HVAMP MODULE
DETECTOR
FUSES
100/110 230/240
F1 1.25A 0.63A
F3 1.25A 0.63A
+5VDC
+/-12VDC POWER SUPPLY
+5VDC
+/-12VDC
X-RAY RELAY
FUSES
F5 0.63A
F6 0.63A
+28VDC POWER SUPPLY
MAX
F1 0.5A
- HV POWER SUPPLY
+HV POWER SUPPLY
XORB

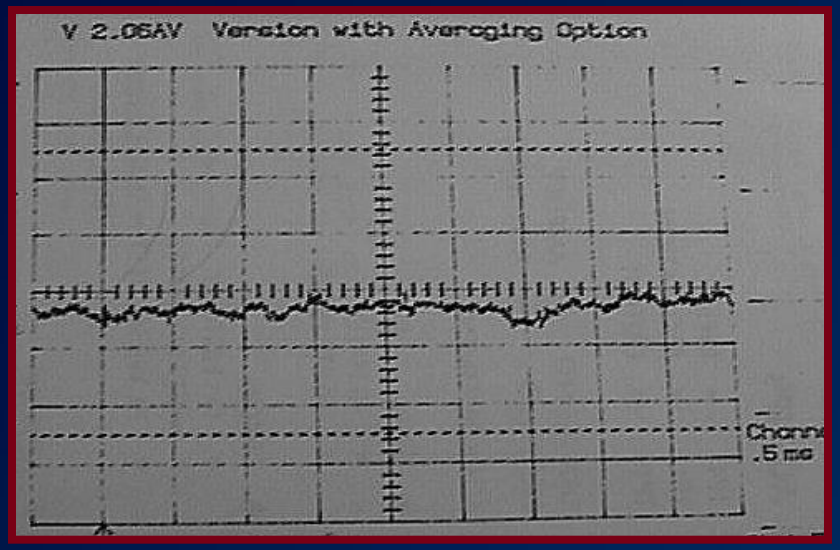
Troubleshooting

Troubleshooting the AGS System

- Signs
  - Low BMD
  - Total Body Scans have Halo
  - White lines on Femur or Spine Scans
- Checks
  - QA History Look for Air Count flux
  - TP 12 Rollover
  - Aluminum Wedge test checks stability of AGS
- Actions
  - Replace PMT
  - Adjust AGSDCA TP 4 (see Service Manual Section 6.2) tightens window - lessens number of amplify commands

Stable, correctly adjusted AGS

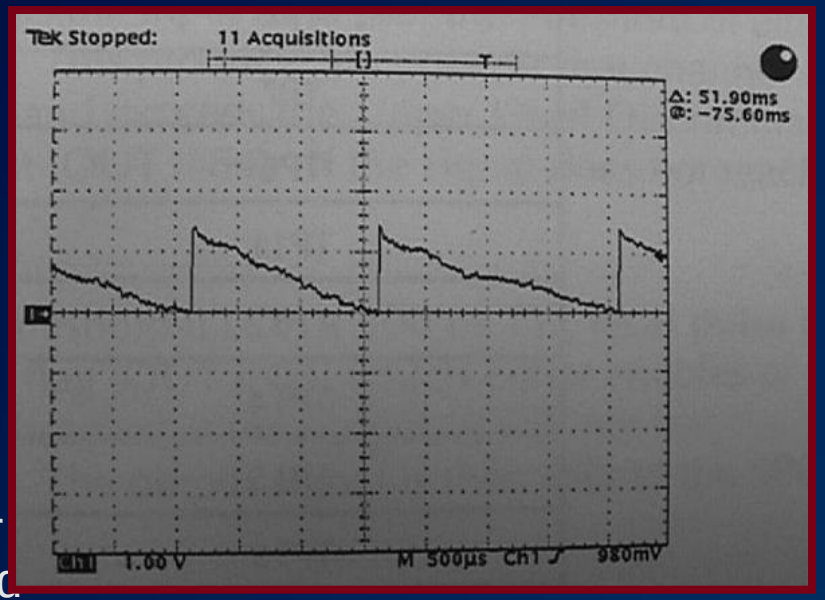
- TP 12 - signal monitor
- Should see stable 2.4 VDC signal (with voltmeter or with oscilloscope)
  - Signal is Amplified or Attenuated based on input from AGS DCA
    - **Desired output is 2.4 VDC Signal**
- If the Signal
  - Spikes UP
    - AGS Rollover
  - Spikes DOWN
    - AGS Rollunder
  - Either condition above is trouble



Test Points	Signal	Expected
TP 1	+ 12 VDC	+ 12 VDC
TP 2	GND	0 VDC
TP 3	-12 VDC	-12 VDC
TP 4	Signal In	2.4 VDC
TP 14	+5 VDC	+ 5 VDC
TP 19	Output	2.4 VDC

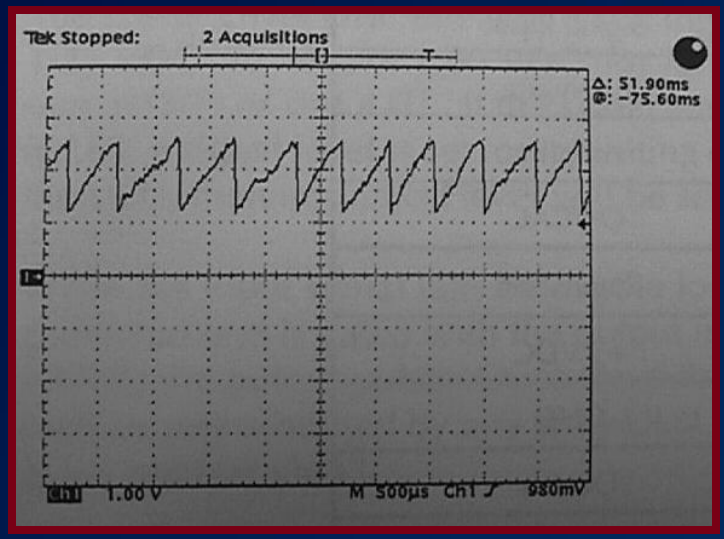
AGS With Rollunder

- TP 12 Monitor
- Peaks Downward - unstable signal
- Signal is coming in too high
  - AGS is sent too many attenuate commands
  - signal out of range
  - the attenuate counters ‘Rollunder’ causing INACCURATE BMD results.
    - Counters reach maximum number of attenuate commands - reset and try to bring signal into range again
  - New detector with old AGS may cause this or a mis-adjusted AGS system



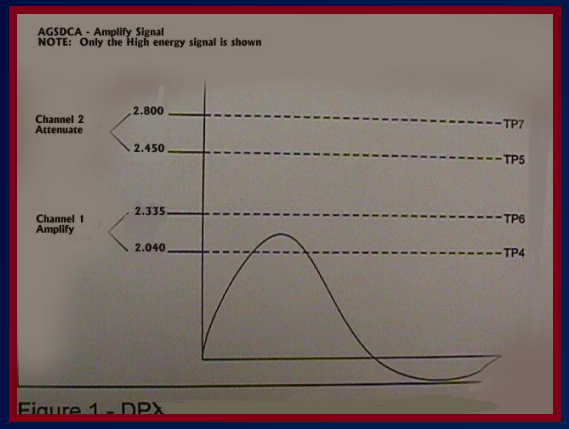
AGS With Rollover

- TP 12 Monitor
  - Unstable signal - peaking upwards
- Rollover
  - signal comes in too low in window
  - too many amplify commands sent to AGS -
  - the amplify counters ‘Rollover’ causing INACCURATE BMD results.
    - Counters reach maximum and reset to lowest setting
    - try and bring signal back into range
  - Causes: deteriorating detector, weak amplifier, bad ground or signal cable mis-adjusted AGS system

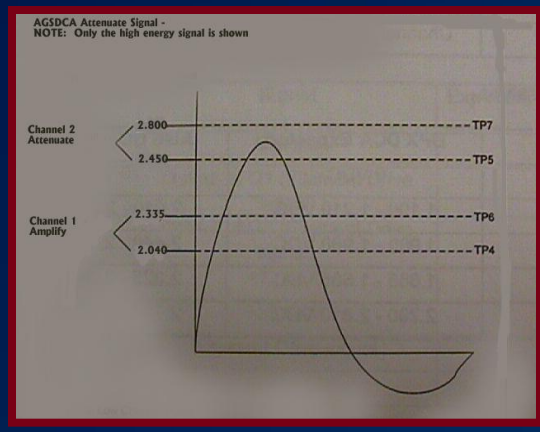


AGSDCA: Produces Gain Control Data for the AGS

- Provides Amplify or Attenuate signal to AGS Board
- 2 Windows
  - Amplify if Signal comes in Low
  - Attenuate if signal comes in High
- One of the two LED's on the AGS will flash each time an amplify or attenuate signal is sent by the AGSDCA
- Note this is a logic signal - not the actual data signal being sent back to the AGS
- Electronically identical to DPXDCA, however, potentiometer settings are very different



High energy signal is in Channel 1 window - sends “Amplify” command to the AGS



High energy signal is in Channel 2 window - sends “Attenuate” command to the AGS

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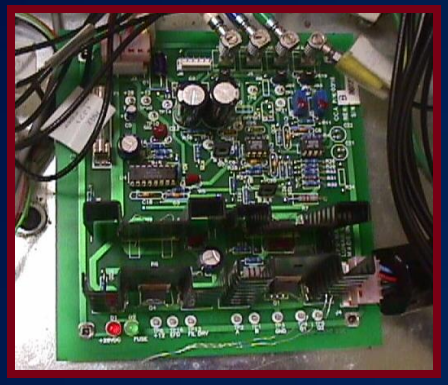
Troubleshooting the MAX Board

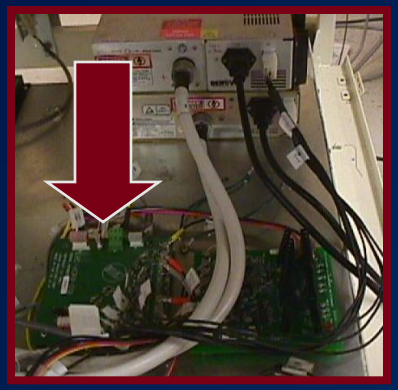
- Red - + 28V DC present Green - Fuse is good
- LED's will only be lit when the relay is triggered
- Troubleshooting tip - TP4, TP5 and TP13 should be continuous when the Tube Head control cable is hooked up
  - **Indicates TH Filament is good**



Test Point	Signal	Expected @ 76kV .750mA
TP 3	Ground	0.000 VDC
TP 4	Q1 Output (Filament Drive Signal)	~ 16 VDC
TP 5	Q2 Output (Filament Drive Signal)	~ 16 VDC
TP 6	+ 12 VDC	+ 12 VDC
TP12	+ 28 VDC	+28 VDC
TP 13	Filament Drive Signal	~16 VDC
TP 14	- 12 VDC	-12 VDC

Troubleshooting with the XORB

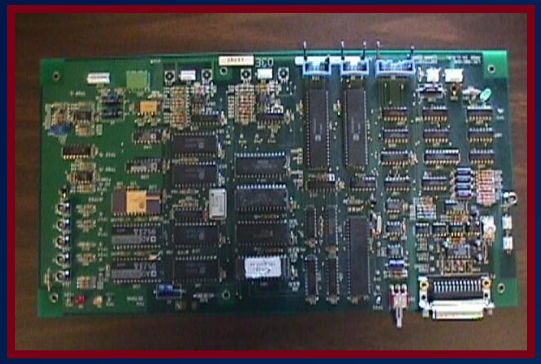
- If ramping trouble exists TP 1, 5, 2 and 6 good troubleshooting guides
- current ramping signal
  - ~ 7 sec after SBC receives command to generate x-rays
- voltage ramping signal
  - ~ 7 sec after SBC receives command to generate x-rays



Test Point	Signal	Expected @ 76kV and .750mA
TP1	-uA Monitor	.750 VDC
TP2	-kV Monitor	3.800 VDC
TP3	-kV Programming	3.800 VDC
TP5	+uA Monitor	.750 VDC
TP6	+kV Monitor	3.800 VDC
TP7	+kV Programming	3.800 VDC

Troubleshooting at the SBC

Test Point	Signal	Expected @ 76kV .75mA
TP 18	PMT HV Feedback	1 VDC / 1000V at detector
TP14	Current Set	.750 VDC
TP 17	Current Feedback	.750 VDC
TP 15	kV Set	3.80 VDC
TP 16	+ kV Feedback	3.80 VDC
TP 24	- kV Feedback	3.80 VDC



LED	Power Present
Green	+ 5 VDC
Red	+12 VDC
Amber	-12 VDC

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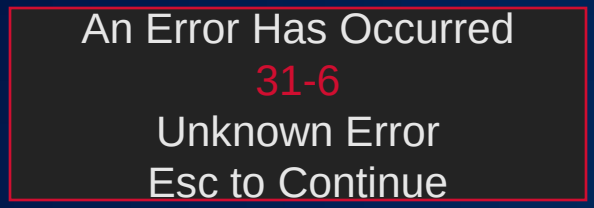
Unknown errors

- 31-6 errors
  - multiple error events occurring at the same time
    - thermostat and +28VDC errors
    - A thermostat error disables the +28 VDC so a 31-6 is typically a thermostat error
    - An arc may also cause an error in the MAX which sends a false thermostat error
    - The tube head thermostat never opens because of heat, typically this is a tube head control cable failure or a short inside the tube



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Error Detection: Sensing System Faults

- Emergency Stop Detection
- Error Detection
  - Motion Detection
    - Signal sent by OMI Board
    - Monitor on Pin 2 of J 13 ONIK Board
- This section of the board detects system faults - it then sends a signal to the SBC to shut down X-Ray production and mechanics
  - Hard interrupt signal is sent via J19 causing motors and x-ray shutdown
  - error determination follows

Errors Detected by OINK

HEX Code	Error	Possible Cause
15-4	Transverse Motion	OMI signal lost Continuous resetting of watch dog on OINK
23-3	Longitudinal Motion	OMI signal lost Continuous resetting of watch dog on OINK
27-2	+28VDC PS	Loss of power to TH (via MAX and/ or OINK)
29-1	E-Stop	E-Stop circuit open (OINK)
30-0	TH Thermostat	TH thermostat circuit open (OINK)
31-6	Unknown	Any of the above

An Error Has Occurred
15-4
Transverse Mechanics
Esc to Continue

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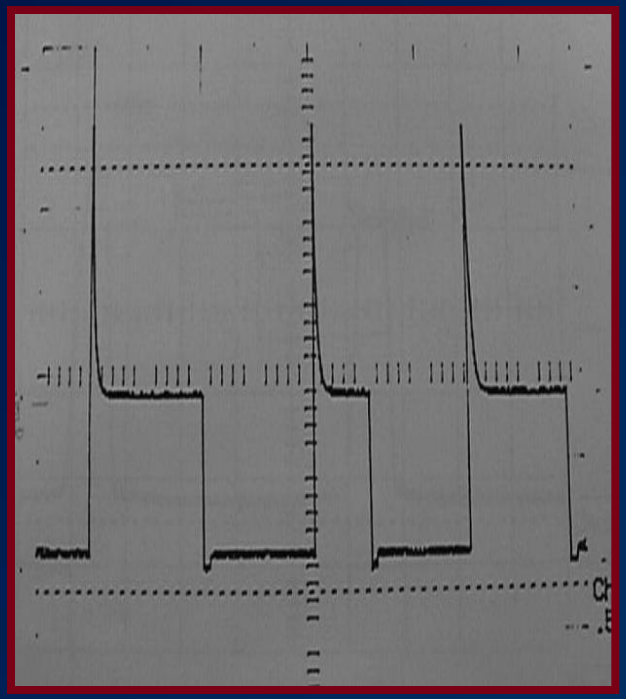
Control and Sensing of the Shutter and Collimator

- Solenoid control - from SBC to OINK
  - Actuation Pulse
    - 26 VDC to Open
    - Drops to hold current when Limit switch is tripped
    - Newest OINK (Rev L) continuously triggers shutter to hold open
- Limit Switches
  - Sense Position of Slides in Collimator used as feedback mechanism

Collimator Actuation Pulse



Measured at OINK Board Anode of D2

DPX Series X-Ray Generation

- + 28 VDC must be present to enable the tube head filament
  - via a transistor
- kV at HVPS must also be present to enable filament current
  - loss of kV or 28 VDC disables filament current
- mA feedback from HVPS and mA program from SBC drive filament current per voltage from SBC
  - Zero mA feedback causes full drive of the filament current which will immediately correct itself (under normal operating conditions) because of the feedback control loop
  - an arc or a short will cause a ramping failure
  - If SBC drive signal and mA feedback are equal - the filament drive stays the same
- A kV spike may not cause a system fault, but due to V=RI, the current must increase, this causes our count rate to increase causing white lines as the detector becomes saturated
  - If scanner errors it will be a single line entry kV mA out of spec - typically mA will be high due to the principle described above

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